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MEMOIRS

OF THE

TORREY BOTANICAL CLUB

VOL. XVII

PROCEEDINGS

OF THE

SEMI-CENTENNIAL ANNIVERSARY

OF THE

TORREY BOTANICAL CLUB

OCTOBER 18, 19 AND 20, 1917

ISSUED JUNE 10, 1918

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PRESS OF
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PREFACE

Of the papers presented at the celebration of the Semi-centennial Anniversary of the Torrey Botanical Club, one, "The ferns of tropical Florida" by John K. Small, has already been published elsewhere (Am. Mus. Jour. **18**: 126–134. 1918); another, on "Bermuda Algae" by Marshall A. Howe, was, in substance, an illustrated summary of a contribution to Britton's "Flora of Bermuda," recently published, and is not here reproduced; in a somewhat similar way, the paper on the "Flora of the Rocky Mountains and adjacent plains" by P. A. Rydberg was in considerable part a summary of the principal results attained in the author's book of that title, then issuing from the press. A few other papers actually presented or read by title are omitted either because copy failed to reach the editor in season or because arrangements had been made for publication elsewhere. Such papers include "Fossil plants from Porto Rico" by Arthur Hollick, "A cotton-rust epidemic in Texas" by E. W. Olive, "The flora of the Isle of Pines, Cuba," by N. L. Britton and Percy Wilson, "The route taken by Capt. Nathaniel J. Wyeth and Mr. Thomas Nuttall from the Mississippi River to the Columbia River in 1843" by W. W. Eggleston, "Comparative cultures of seed-plants in desert valley, desert mountain, and coastal locations" by D. T. MacDougal, "The Vegetation of Montauk, Long Island" by Norman Taylor, and "Parthenocarpy in cucumbers" by A. F. Blakeslee and P. A. Warren.

MARSHALL A. HOWE,
Editor

ERRATA

Page 7, following line 23, insert "Torrey Botanical Club reminiscences" by Dr. Arthur Hollick.

Page 49, line 4, for *Transchelia*, read *Tranzschelia*.

Page 58, line 4 from bottom, for *Triblidiella* read *Tryblidiella*.

Page 58, line 2 from bottom, for *rufula*, read *rufulum*.

Page 69, line 2, for *paradisica*, read *paradisiaca*.

Page 176, last line, for *fasiculare*, read *fasciculare*.

Page 178, line 14, for *decepiens*, read *decipiens*.

PROCEEDINGS

OF THE

SEMI-CENTENNIAL ANNIVERSARY

OF THE

TORREY BOTANICAL CLUB

OCTOBER 18, 19 AND 20, 1917

MEETING OF THURSDAY, OCTOBER 18

The meeting of October 18 was held in the lecture-room of the Department of Botany of Columbia University in Schermerhorn Hall, beginning at 2:10 P. M., with Professor Herbert M. Richards, President of the Club, in the chair. Fifty-five persons, mostly members of the Club, were present.

President Richards, in his opening remarks, referred to the importance of the occasion and expressed his appreciation of the honor of presiding at such an anniversary gathering.

Dr. R. A. Harper, Torrey Professor of Botany in Columbia University, recalled the intimate associations of the Torrey Botanical Club and the Department of Botany of Columbia University, and on behalf of the University extended to the Club felicitations on its Fiftieth Anniversary and a most cordial welcome to the University.

The following historical, reminiscent, and scientific papers,* most of which are published in full in this Anniversary Memoir, were then presented:

"History of the Torrey Botanical Club," by Dr. John Hendley Barnhart.

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* Invitations to present papers were, in the intent of the committee, restricted to actual members of the Club. In the program as rendered there were few deviations from this limitation.

"Reminiscences," by Rev. Dr. H. M. Denslow.

"A sketch of the life of Coe Finch Austin," by Mrs. Abraham Demarest (Sarah Elizabeth Austin).

"Torrey Botanical Club reminiscences," by Dr. N. L. Britton.

"Contact and pressure reactions in *Pediastrum simplex*," by Professor R. A. Harper. Illustrated by lantern-slides. Discussion by Drs. N. L. Britton, A. F. Blakeslee, E. W. Olive, and J. H. Barnhart and Professor G. F. Atkinson.

"The origin of the Hawaiian flora," by Professor Douglas Houghton Campbell. (Read by title in absence of the author.)

"Uredinales of Cuba," by Professor J. C. Arthur and Mr. J. R. Johnston. (Read by title in absence of authors.)

"Six misunderstood species of *Amanita*," by Professor George F. Atkinson. Illustrated by lantern-slides.

"*Sisyrinchium Bermudiana* Linnaeus," by Oliver Atkins Farwell. (Read by title in absence of the author.)

"The individuality of the bean-pod as compared with that of the bean-plant," by Helene M. Boas. (Illustrated by charts.)

"Two months in the southern Catskills," by Mr. O. P. Medsger. Illustrated by photographs. Discussion by Dr. N. L. Britton.

"The ferns of tropical Florida," by Dr. John K. Small. Illustrated by map and photographs. Discussion by Dr. N. L. Britton. (Published in Am. Mus. Jour. **18**: 127–135. 1918 [Illust.].)

"Fossil plants from Porto Rico," by Dr. Arthur Hollick. (Read by title in absence of the author.)

"A cotton-rust epidemic in Texas," by Dr. E. W. Olive. Discussion by Professor G. F. Atkinson.

"Bermuda Algae," by Dr. Marshall A. Howe. Illustrated by lantern-slides. Discussion by Drs. Tracy E. Hazen and N. L. Britton. (Published in more extended form in Britton, N. L., "Flora of Bermuda," in press at the time of presentation.)

"Some factors influencing the stimulative action of zinc sulphate on the growth of *Aspergillus niger*," by Mr. R. A. Steinberg. (Introduced by Professor R. A. Harper.) Discussion by Professors George F. Atkinson and Herbert M. Richards and Drs. N. L. Britton and A. F. Blakeslee.

"Centrosomes in fertilization stages of *Preissia quadrata*," by Dr. Margaret A. Graham. Illustrated by lantern-slides.

"Philippine Micromycetous Fungi," by Professor Paul Weidemeyer Graff. (Read by title in absence of the author.)

"A method of teaching economic botany," by Professor Edward S. Burgess. (Read by title in absence of the author.)

After the presentation of the above papers, adjournment was made to the Columbia University Faculty Club, where dinner was served to thirty-seven persons. Following the dinner, there was an informal discussion of the proposal to establish in America a Botanical Abstract Journal.

DR. W. A. MURRILL, editor of *Mycologia*, introduced the subject of the evening by referring to correspondence with Dr. Donald Reddick, editor of *Phytopathology*, and by outlining various phases of the subject that seemed to need discussion at this time. He spoke of the work already done by the *Bulletin of the Torrey Botanical Club*, *Mycologia*, and *Phytopathology*, in connection with the indexing and abstracting of botanical literature. Applied botany, according to Dr. Murrill, is now looked after pretty well by the U. S. Department of Agriculture, but the Government's work in this line could hardly be extended to include purely scientific articles. Original articles are now going begging, especially costly illustrated ones. It might be possible to reduce the pressure on existing journals by greatly condensing some of these articles and preventing the duplication of material in various publications. To make a new abstract journal a success would require a paid board of editors, and a prompt, complete, and accurate account of all botanical publications. This would be a very expensive and arduous undertaking and such a journal would have to compete with the *Botanisches Centralblatt* when the war is over.

DR. C. STUART GAGER, in emphasizing the need of such a publication as "Botanical Abstracts," referred to the inadequacy of the botanical portion of *Experiment Station Record*, on account of its omissions, and its custom of translating all foreign-language titles into English, thereby making citations difficult. Reference was also made to the recent enormous increase in the bulk of botanical publication, rendering it practically impossible for any one to keep in touch with the literature by depending on original sources. The opinion was expressed that the "Abstracts" should not endeavor to be full enough to render the reading of the original papers unnecessary (as one speaker had suggested). Lack of funds seems to be the only obstacle to launching the enterprise, and no adequate source of funds seems to be in sight.

MR. NORMAN TAYLOR, editor of *Torreya*, made the suggestion that the Torrey Botanical Club so change the character of *Torreya* that it would be entirely of an Abstract nature. The desirability of enlarging that journal to accommodate the greater amount of material involved in the proposed scheme was urged, particularly in view of the facts that the necessary steps in the inauguration of a new journal must be somewhat slow and halting, and that *Torreya*, with a slight modification of existing conditions, could be made available at once. The income now set aside from Club dues and that derived from subscriptions would have to be augmented from other sources. The proposal was made that financial assistance for the first two years should be guaranteed by the Club and that subsequently the greatly increased circulation of *Torreya*, in its new form, would tend to make it a self-sustaining journal.

PROFESSOR R. A. HARPER emphasized the need of critical reviews, as well as colorless abstracts, with a view to raising the general standards of our work and perhaps in some cases to reducing the length and number of papers published.

DR. N. L. BRITTON gave a tentative estimate of the number of pages of such an Abstract Journal and of the probable annual cost of printing.

PROFESSOR GEORGE F. ATKINSON remarked: I have given this subject of an Abstract Journal, to be published in this country, very little thought, although I have known for several months that it has been under consideration by some botanists. What I shall now say on the subject is of course not the result of careful deliberation nor have I had the opportunity of hearing any very definite suggestions concerning the plan, aside from the remarks I have heard this evening, except that the abstracts should be quite full, that the journal should be published in the English language, and that the abstracts should be published within a reasonable time after the appearance of the original contribution.

I have felt that there was a great waste of effort and money in our present plan of abstracts in our current botanical journals, in this country as well as in Europe. The same contribution is reviewed in from five to ten or more journals. To have the journals for their original contributions, we are obliged to pay for all this reduplication of abstracts, or if we take the journal for the abstracts chiefly, we must subscribe to a dozen or more and still pay for this needless duplication.

It has occurred to me that if we cannot have one complete Abstract Journal, perhaps the managers of our present journals, in this country at least, might arrange for a classification and division of abstracts and thus avoid duplication. For example one journal might confine its abstracts to morphology and physiology, another to taxonomy, another to plant pathology, and so on.

I do not think an Abstract Journal for American botany alone would meet the situation. Nearly every botanist in America now has access to nearly all, or all, of American publications. What we need is a journal which is complete and will give us suitable abstracts of botanical contributions (original) from all parts of the world no matter what language the original is published in. I believe practically all of our botanists in this country would be willing to pay $10 a year for such an Abstract Journal. I think bacteriology should be excluded, for bacteriologists will have their own abstracts, and I would exclude abstracts of remedial measures for plant diseases.

I believe such an Abstract Journal should aim to be the organ of communication for the botanists of the world. I believe it should admit abstracts in at least three different languages (English, French and German) according to the wish of the writer of the review, unless the journal can be put on a sufficient financial basis to have a strongly centralized organization.

I doubt if the Torrey Botanical Club alone could swing such a proposition. If such an Abstract Journal could receive a sufficient foundation, either from a personal donor, or from some existing institution, as has been suggested, so that a central bureau in New York or Washington could prepare the abstracts and publish the journal, it would render a great service to the botany of the world and particularly of this country.

DR. J. HENDLEY BARNHART said: In this matter, as in some others, I fear that I am a pessimist. This is a great project, and an attractive one, and I do not like to seem to be trying to throw cold water on it. But I fear that those who are backing the venture do not realize as fully as I do the difficulties to be met. If the proposed abstract journal is to be undertaken, it should be commenced at once, for the need is great, the time is ripe, and the opportunity, if lost, may never come again. But the attempt to abstract American botanical literature only is not worth while; the world-field is vast; the journal would inevitably exceed in size and cost the limits estimated in advance. If done at all, it should be well done. And it must not be forgotten that, as a rule, persons competent to prepare reliable abstracts are also fitted for original investigation, and it is always difficult to induce an investigator to lay aside his chosen work long enough to write out reports upon the work of others.

After all, however, adequate financial subsidy at the beginning, continued as long as necessary, perhaps indefinitely, is the most essential requirement. Given this, and competent editorial management, and it *can be done.* And in that case it surely *ought to be done.*

I am strongly in favor of absolutely "colorless" abstracts as contrasted with critical reviews. Indeed, in an undertaking like this, which depends for its success upon universal coöperation, any other course is sure to lead to friction, then to open breaks, and eventually to complete ruin. Opinions expressed would be, after all, merely individual opinions, and liable to greater error than the views criticized. Form and method of presentation might be safely, and perhaps should be fearlessly, criticized; but criticism of statements of facts and soundness of theories should be studiously avoided. Each abstract should attempt to mirror, in miniature, the contents of the book or paper abstracted. An *abstract* journal is no place for *reviews.*

DR. ALFRED GUNDERSEN inquired if it would be practicable for the editors of the proposed journal to coöperate with such publications as the *International Catalogue of Scientific Literature* or the *Botanisches Centralblatt.* In France, in several cases, the same botanist has been reporting to both of these.

DR. MARSHALL A. HOWE remarked that the matters of publishing more reviews and abstracts in *Torreya* and of increasing the number of titles relating to phytopathology in the Index to American Botanical Literature published in the *Bulletin* had already been referred to the Board of Editors for consideration, and that while the editors had approved moderate increases in these directions, they had felt somewhat appalled by the magnitude of the more recent and more ambitious proposals, which, however, they had thus far discussed without the formality of a regular meeting of the Board.

DR. E. W. OLIVE suggested that the proposed publishing of Botanical Abstracts might possibly be subsidized, at least in part, by the two botanical gardens of New York City. In this great financial capital of the nation, it ought to be easy to secure a substantial backing for such an important venture and one fraught with such obvious possibilities for scientific progress. Such a proposition should readily draw from the commercial world strong financial support, especially if in the appeal to them the more economic phases of the broad field of botany were emphasized. It may be that all that is necessary for the securing of the necessary funds for the founding of the proposed new journal is that Director Britton and Director Gager should ask their friends of Wall Street for their support of the project.

On the motion of Dr. Gager it was voted that a committee consisting of the Board of Editors and four other persons be appointed by the President to consider the matter of establishing an American Botanical Abstract Journal.

President Richards stated that he would announce at a later meeting the names of the four persons to serve with the Board of Editors to constitute such a special committee.

On the motion of Dr. Gager a vote of thanks to Columbia University and members of its botanical staff for the hospitalities of the day was unanimously passed.

MEETING OF FRIDAY, OCTOBER 19

The meeting of October 19 was held at the Mansion, New York Botanical Garden, beginning at 2:20 P. M., with Dr. John Hendley Barnhart, Vice-president of the Club, in the chair. Fifty-four persons were present.

It was announced that President Richards had appointed Dr. N. L. Britton, Professor R. A. Harper, Dr. C. Stuart Gager, and Dr. J. Hendley Barnhart to serve with the Board of Editors as a special committee on a proposed American Botanical Abstract Journal.

Dr. N. L. Britton, Director-in-Chief of the New York Botanical Garden, in extending a welcome to the Club, referred to the fact that the existence of the Garden was due to the activities of a special committee of the Torrey Botanical Club.

The following papers were then presented:

"The flora of the Isle of Pines, Cuba," by Dr. N. L. Britton and Mr. Percy Wilson. Illustrated by lantern-slides.

"Observations on the development of *Peridermium Cerebrum*," by Dr. B. O. Dodge and Professor James F. Adams.

"Collecting Fungi at Delaware Water Gap," by Dr. W. A. Murrill. Illustrated by photographs.

"The physiological properties of two species of poisonous mushrooms," by Dr. Michael Levine. Questions and discussion by Professors Harper, Atkinson, and Rusby, and Drs. Gager and Murrill.

"Flora of the Rocky Mountains and adjacent plains," by Dr. P. A. Rydberg. Illustrated by maps. (This was a historical sketch of the work of the various botanical collectors and writers who had dealt with the flora of the region named, concluding with a summary of the results shown in large book on the subject written by the speaker and soon to be published.)

"The route taken by Capt. Nathaniel J. Wyeth and Mr. Thomas Nuttall from the Mississippi River to the Columbia River in 1834," by W. W. Eggleston. (Read by title in absence of the author. To be published by the U. S. Department of Agriculture),

"Statistical studies in *Cichorium*," by Dr. A. B. Stout.

"The origin and development of the lamellae in *Schizophyllum commune*," by Professor James F. Adams.

"The effect of acids and alkalies on the growth of the protoplasm of pollen-tubes," by Professor Francis E. Lloyd. (Read by title in absence of the author.)

"Recent botanical exploration in Colombia," by Professor H. H. Rusby.

At the close of the arranged program, Dr. N. L. Britton exhibited architects' plans for recent and future constructions in the development of the New York Botanical Garden. Refreshments were then served, after which visits were made to the new Rose Garden and other points of special interest in the vicinity of the Mansion.

MEETING OF SATURDAY, OCTOBER 20

The meeting of October 20 was held in the lecture-hall of the Brooklyn Botanic Garden, beginning at 2:20 P. M., with Dr. C. Stuart Gager, Vice-president of the Club, in the chair. Seventy persons were present. Dr. Gager, in behalf of the Brooklyn Botanic Garden, made a brief address of welcome, after which the following papers were presented:

"Determination of acidity in plant tissues," by Professor Herbert M. Richards.

"The osmotic concentration of the tissue fluids of desert Loranthaceae," by Dr. J. Arthur Harris. Discussion by Professor R. A. Harper.

"Early horticultural journalism in the United States," by Mr. James G. Scott.

"A preliminary report on the *Russulae* of Long Island," by Dr. Gertrude S. Burlingham. Illustrated by specimens. Discussion by Dr. W. A. Murrill and Mr. Norman Taylor.

"Comparative cultures of seed-plants in desert valley, desert mountain, and coastal locations," by Dr. D. T. MacDougal. (Read by title in absence of the author.)

"Life-history studies in *Sclerotinia*," by Dr. F. J. Seaver and Professor W. T. Horne. Illustrated by photographs and drawings.

"The vegetation of the Hempstead Plains, Long Island," by Dr. Roland M. Harper. Illustrated by lantern-slides.

"The vegetation of Montauk, Long Island," by Mr. Norman Taylor. Illustrated by lantern-slides. (To be published, in a more extended form, by the Boooklyn Botanic Garden.)

"Weather conditions and crop diseases in Texas," by Dr. F. H. Blodgett. (Read by title in absence of the author.)

"Inheritance of height in peas," by Dr. O. E. White. (Read by title in absence of the author.)

"Parthenocarpy in cucumbers," by Dr. A. F. Blakeslee and Mr. P. A. Warren. Illustrated by lantern-slides.

"Trimorphism and insect visitors of *Pontederia*," by Dr. Tracy E. Hazen. Illustrated by lantern-slides.

Dr. Marshall A. Howe, in behalf of Dr. N. L. Britton, chairman of the Committee on the Fiftieth Anniversary, reported that subscriptions to the special Anniversary fund amounted, up to date, to $1,854, with about one third of the enrolled members subscribing.

On motion of Professor Robert A. Harper, a vote of thanks was extended to the Director and other officers of the Brooklyn Botanic Garden for their hospitality in connection with the Club's Anniversary.

Professor Herbert M. Richards, in moving a special vote of thanks to the chairman of the Committee on the Fiftieth Anniversary, made the following remarks:

Mr. Chairman: I should like to offer another motion for a vote of thanks and at the same time to make a few remarks. If I may be permitted I will begin in a reminiscent vein. It has just occurred to me that I have now attained my majority as one of the botanical group in New York City. It was twenty-one years ago this month when I attended my first meeting of this Club. That same autumn a little dinner was given to some of the newcomers, of whom I was one. I remember that it struck me at the time and has been even more forcibly impressed on me since that the activating force, the activating energy, in the botanical development of this region centered to a preponderating extent in one individual. You all know whom I mean. It was he who really organized the botanical department of Columbia University and who was its first professor. It was he also who was largely responsible for the organization of the New York Botanical Garden. As members of the Torrey Botanical Club we all rightly pride ourselves upon the influence of the Club as a whole in bringing about the foundation of that institution. It is, however, no disparagement to the devotion of the non-professional members to say that had there not been a professional botanist back of the movement who was not only a man of vision, but also one of unusual organizing ability, the Garden would not have developed at the time or in the manner in which it did. I think that you will agree with me, Mr. Chairman, that even this Garden where we now are was influenced in its initiation in no small measure by the importance and success of its elder sister in Bronx Park. Finally, in a less important way perhaps, the same efficient loyalty to botany has been shown in the arrangement and the carrying through of this Semi-centennial Celebration of our Club, which we owe to the chairman of our special committee.

I would, therefore, like to offer a motion for a vote of thanks to be extended by the club to Dr. N. L. Britton, Director-in-Chief of the New York Botanical Garden and Dean of our botanical fraternity here.

The motion was unanimously carried.

After the serving of tea in the rotunda of the library, the members of the Club inspected some of the more attractive and interesting features of the grounds of the Brooklyn Botanic Garden under the guidance of Dr. C. Stuart Gager and other members of the Garden staff.

The following members of the Club were present at one or more of the three meetings held in connection with the Semi-centennial Anniversary.

Adams, James F.
Atkinson, George F.
Banker, H. J.
Barnhart, John H.
Benedict, Ralph C.
Blakeslee, A. F.
Boas, Helene M.
Boynton, K. R.
Britton, E. G.
Britton, N. L.
Broadhurst, Jean
Burgess, Edward S.
Burlingham, Gertrude S.
Cassebeer, H. A., Jr.
Chamberlain, Edward B.
Concanon, J. J.

Coutant, Mary W.
Denslow, H. M.
Dodge, B. O.
Douglas, H. B.
Enquist, John
Evans, A. W.
Gager, C. Stuart
Graham, Margaret A.
Gundersen, Alfred L.
Harper, Robert A.
Harper, Roland M.
Harris, J. A.
Hazen, Tracy E.
Hollick, Arthur
Howe, Marshall A.
Jones, James H.
Jud, Friedolina C.
Kaufman, Pauline
Keeler, Mrs. L. M.
Levine, Michael
Levy, Daisy
Lorenz, Annie
Mansfield, William
Marquette, William
Medsger, O. P.
Mulford, Fanny A.
Murrill, William A.
Nash, George V.
Olive, E. W.
Richards, Mrs. H. M.
Richards, H. M.
Robinson, Winifred J.
Rusby, H. H.
Rydberg, Per Axel
Scholl, Edith
Scott, James G.
Seaver, F. J.
Small, John K.
Smith, Annie Morrill
Stewart, Grace
Stout, A. B.
Taylor, Norman
Thomas, Mrs. H. Mark
Tweedy, Alice B.
Williams, R. S.
Wilson, Percy

HISTORICAL SKETCH OF THE TORREY BOTANICAL CLUB

By John Hendley Barnhart

The New York Botanical Garden

The Torrey Botanical Club developed so gradually from a mere group of associated botanical enthusiasts into a full-fledged scientific society that it is quite impossible to fix upon an exact date of origin which might not be honestly disputed. In an early number of the *Bulletin*, the beginnings of the Club are traced to "the summer of 1866";* a few years later the editor remarked in a footnote "not later than 1865";† in later years Dr. Allen, one of the earliest members, is said to have claimed as early a date as 1858,‡ but there is nothing to verify this claim, and it is possible that he has been misquoted. Dr. Thurber, in his inaugural address as president of the Club, in 1873, when many if not most of the original members of the Club must have been among his auditors, declared frankly: "We have no record of the date of the beginning of the Club."§

The earliest positive evidence of the existence of an association which can be definitely connected with our present organization seems to be a small printed notice preserved in our archives. It is dated at the office of the *American Agriculturist*, December 10, 1867, signed by George Thurber and Thomas Hogg, and calls a meeting of "the Botanical Club, to be held at this office on Saturday, the 14th inst., at 2 o'clock P. M. A full attendance is desired, in order that final arrangements may be made for the festival of the 20th." Presumably the meeting thus called was duly held, for on the 20th the Club gathered, with various botanically distinguished guests from out of town, to enjoy a supper at the Astor House. The occasion was the celebration of the fiftieth anni-

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* Bull. Torrey Club 1: 45. 1870.

† Bull. Torrey Club 4: 26. 1873.

‡ Bull. Torrey Club 27: 552. 1900.

§ Bull. Torrey Club 4: 26. 1873.

versary of the presentation (December 22, 1817) by Dr. Torrey, to the Lyceum of Natural History, of the manuscript of his catalogue of plants growing spontaneously within thirty miles of the city of New York. An account of the celebration was published at the time in the *American Naturalist*,* and in the *Bulletin*, a few years later, it is clearly stated that it "still further united the members, *and the present organization was* effected."† It is at least from as early as December 20, 1867, therefore, that we may without dispute date the establishment of the Club; and it is that date of which we are now (somewhat prematurely) celebrating the fiftieth anniversary. Unfortunately, no complete list of those present at the meeting of organization has been preserved, and if we do not count the guests, only eleven members of the Club are positively known to have been there; it is probable, however, that there were fifteen or more.

For the years 1868 and 1869 there are no records of the Club extant, although regular monthly meetings seem to have been held throughout the year, both winter and summer. The speaker has in his possession an original written notice referring to the meeting of February, 1868, which reads: "The meeting of the Botanical Club is unavoidably postponed until Friday eve. next, Feby 21st." The same year, June 30, the Club lost its first member by death: William Wallace Denslow, "one of the earliest, most enthusiastic, and, with the disadvantage of feeble health, one of the most indefatigable."‡

The beginning of the year 1870 found the Club still a very informal association. It had no written constitution, no officers, no formal list of its membership. It was even without a name, being known to its members familiarly as "the Club," or more formally as "the Botanical Club," and to outsiders as the "Botanical Club of New York." At this time William H. Leggett, one of the earliest and most faithful of the founders, started, as a private venture, a modest four-page monthly sheet to which he gave the name "Bulletin of the Torrey Botanical Club." Of course this journal, which was the first botanical periodical in America, was issued with the approval of the Club, but the entire

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* Am. Nat. 2: 41–47. 1868.

† Bull. Torrey Club 1: 45. 1870.

‡ Bull. Torrey Club 1: 45. 1870.

financial responsibility rested with the editor for many years, and American botany will ever be indebted to the memory of Leggett for the powerful and helpful influence thus exerted by him upon its development at a critical period. It is not by accident that even the latest volume of the *Bulletin* bears upon its title-page the inscription "Founded by William Henry Leggett, 1870."

The name "Torrey Botanical Club" made its first appearance in public upon the first page of the first number of the *Bulletin*, and it is a tradition among us that this name was selected and applied to the Club, by the editor, in order to have what he regarded as a satisfactory name for his periodical, and was thereupon accepted without question (except for mild protest on the part of the modest president, Dr. Torrey) by the other members. In any event, and however it originated, the name "stuck," and has never been altered to this day, in spite of the very different kind of associations to which the name "Club" is now commonly applied.

The first list of officers and members was published in the *Bulletin* for December, 1870. The editor mentions that "the association is rather informal, and somewhat fluctuating," and apologizes for any consequent "errors and deficiencies." The list (including W. W. Denslow, mentioned as already deceased) comprises thirty names; and these persons have ever since been regarded as the founders of the Club, although it is certain that not all of them had been members from 1867. There is one notable omission from the list; namely, Thomas Hogg, whose name was one of those signed to the printed call of December 10, 1867 (as already mentioned), and who was certainly a member of the Club both before and after the date of the printed list, so that the omission of his name was probably an oversight. The addition of his name makes the number of "founders" (that is, members prior to 1871) thirty-one. When Dr. Timothy Field Allen died in 1902, it was supposed by most of the members of the Club that he was the last surviving founder; when James Hyatt died in 1904, it was stated in *Torreya* that he was the last. James Sheldon Merriam, however, did not die until 1908, and at least two of those whose names appear on the list of December, 1870, are still living. These are Charles Belknap Gerard, now of Muskogee, Oklahoma, and Rev. Dr. Herbert McKenzie Denslow, who has again, after a long interval, been one of our fellow-members for the last seven years.

In 1871 the Club decided upon incorporation, desiring, as it was facetiously expressed by Dr. Thurber, to "enjoy the privilege of sueing and being sued." An act of incorporation was passed by the Assembly of the State of New York, April 21, 1871, but it was seriously defective, and the Club refused to accept it and failed to organize in compliance with its provisions. The first defect, for which it is not unlikely that Dr. Torrey was responsible, was that the corporate name was given as the "New York Botanical Club." The other defect was a mere reflection of the corrupt politics of that period, and consisted in the inclusion among the incorporators of two members of the infamous "Tweed ring." To remedy the defects the act was amended by the legislature, April 29, 1872, but even then the Club was very slow to effect organization under its provisions. The charter was accepted unanimously at the meeting of January 7, 1873, and a committee appointed to draft a constitution and by-laws; but these were not adopted until March 25, and the first officers were not elected in accordance with them until April 29.

Meanwhile, on the tenth of March, the beloved president, whose inspiring influence had brought the Club into existence, and whose name it bore, Professor John Torrey, had breathed his last, and the Club had become a monument to his memory. Few are the botanists now living who remember Torrey, but his kindness, his gentleness, his patience, his earnestness, his scholarship—these still seem vividly real, even to us who know them only by the recorded testimony of those who both respected and loved him. The Torrey Botanical Club could bear no name more deserving of honor.

The first president elected under the provisions of the new constitution was Dr. George Thurber, well known as a student of grasses. He had been botanist to the Mexican Boundary Survey, and first head of the department of botany at the Michigan agricultural college, before coming to New York; and he was at this time, and for many years afterward, editor of the *American Agriculturist.* Fortunate it is that his inaugural address, rich in reminiscence, was printed in full in the *Bulletin.* The vice-presidency, a new office at this time, was filled by the election of Dr. Timothy Field Allen, to whom tradition credits the first suggestion looking toward the formation of the Club.

Dr. Thurber's presidency covered a period of about seven years. The meeting-place of the Club continued to be the Herbarium of Columbia College, with which Dr. Torrey's memory was so indissolubly associated. The *Bulletin* grew from a four-page to a twelve-page monthly, and the scope of the papers published broadened noticeably. In this connection it may be remarked, however, that although the founders of the Club were mostly collectors, and their efforts were primarily devoted to the botanical exploration of the vicinity of New York City, it is evident that their work was limited only by the meagerness of their knowledge and the narrowness of their opportunity. Their interest in botany was as broad as the science itself, and their concept of the science no narrower, at least, than that of their contemporaries. The early pages of the *Bulletin* were devoted chiefly, it is true, to placing upon record stations for the flowering plants of the local flora; but even before the end of the first volume there was an important illustrated paper on the structure of the flowers and fruit of *Spirodela*, and within a few years the taxonomy of the lower plants began to occupy a conspicuous place. There is no reason to believe that, from the very beginning, any botanical paper was ever excluded from the pages of the *Bulletin* because foreign to its field.

The need of a publication which would serve to assist correspondence between American botanists was filled by the appearance in the *Bulletin* for November, 1873, of a botanical directory for North America; additions and corrections were published in the *Bulletin* from time to time, and two supplements appeared separately; in 1878 a new edition was issued in pamphlet form. The reëstablishment of Cassino's "Naturalists' Directory" rendered further efforts in this direction superfluous. Dr. Thurber was followed in the presidency, in 1880, by John Strong Newberry, professor of geology at Columbia, and famous as a palaeobotanist. Professor Newberry was the president of the Club for ten prosperous years—although the success of the organization then, as before and since, has been due rather to the faithful and correlated labors of devoted members than to the efforts of any one man. This decade saw many changes, recorded in and in some cases reflected by the *Bulletin*. The history of the *Bulletin* before and during this period is admirably summed up in a report printed in the second number of the seventeenth volume.* The journal which had been established as a private venture, and maintained as such for twelve years, was formally taken over by the Club at the beginning of the year 1882, and an associate editor chosen; just in time, for "the morning of April 11 witnessed the death of the genial, talented and earnest editor." Succeeding years saw a rather kaleidoscopic change in the editorial board—there were ten different members in eight years, the largest number at any one time being six—yet the publication showed steady growth and improvement. In 1886, under the editorship of Elizabeth Gertrude Britton and Frederick James Hamilton Merrill, an index to recent American botanical literature was undertaken, which greatly enhanced the value of the *Bulletin* to its readers, and has been maintained in modified form until the present time.

In April, 1888, appeared the Preliminary Catalogue of Anthophyta and Pteridophyta within one hundred miles of New York City, based upon the work of the members of the Torrey Club up to that time. It was a mere check-list, intended as a manual to be used by members for manuscript records of further work, but it was much too extensive for publication in the *Bulletin*, and was issued separately in pamphlet form. Before the end of the year, however, the need for a regular series of Club publications in monographic form had made itself felt, and the establishment of the *Memoirs of the Torrey Botanical Club* had been authorized; the first number made its appearance the following May.

At about the same time the Club began the promotion of a project for a botanical garden. An appeal for such an institution in New York City was adopted January 8, 1889, and distributed with the number of the *Bulletin* for that month. The effort met with various setbacks, and the plans required much modification, but it was the movement inaugurated at this time that eventually resulted in the establishment of the New York Botanical Garden in Bronx Park.

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* Bull. Torrey Club 17: 48–52. 1890.

It was in the fall of 1888, too, that the Club began to hold meetings twice instead of once each month. At first one meeting was called the "regular" one and the other the "adjourned" one, but at the end of the following year (December 10, 1889) a constitutional amendment made the distinction unnecessary.

During the decade, 1880 to 1889, the *Bulletin* had more than doubled in size, the *Memoirs* had been begun, and the active membership of the Club had increased to more than twice its former size. Insufficiency of funds interfered with the development of the Club's activities then as it has ever since; but this very need of financial aid furnished a stimulus to further effort.

In January, 1890, Hon. Addison Brown was elected president. Unlike his predecessors, he was never a professional botanist, but as an amateur had long devoted as much time to his favorite science as could be spared from the responsibilities of his judicial career. He had been vice-president for many years, even during Thurber's presidency, and his elevation to the highest office in the gift of the Club was but a recognition of his faithful interest in its welfare. His services in this office were retained for fifteen years, and terminated only by his insistence upon retirement.

From the beginning of the year 1889, Nathaniel Lord Britton, then instructor in geology and botany (there was at that time no department of botany) at Columbia University, was the editor-in-chief of the publications of the Club, and his invaluable services in that capacity continued for nine years. The *Bulletin* had long held a conspicuous place in American botany, and its prestige was now further strengthened. The reputation of the Club and its editor grew together, and interacted upon each other. Professor Lucien Marcus Underwood, Dr. Britton's successor as professor of botany at Columbia, also followed him, two years later, as editor, and so served for five years, 1898 to 1902; the present speaker's first two years of editorship, 1903 and 1904, coinciding with the last two years of the presidency of Judge Brown.

The summer of 1891 was made notable in our history by the organization of the Scientific Alliance of New York, with the Torrey Botanical Club as one of its constituent societies. This coöperative scheme proved of mutual advantage. The Club benefited by it no less than the others, and remained a member throughout the sixteen years of the Alliance's continuance.

For the first thirty years of its existence, the headquarters of the Club had always remained at Columbia University. At first the meetings were held at the herbarium and afterward, when at last that was outgrown, the Club met for years in Hamilton Hall. In the summer of 1897, Columbia removed from the Madison Avenue and Forty-ninth Street location to the new site on Morningside Heights, and the Torrey Botanical Club at that time transferred its herbarium and changed its meeting-place to the College of Pharmacy, at 115 West 68th Street.

At the beginning of the year 1900 the Club assumed the publication of the Card Index of American botanical literature. This had been issued for the preceding six years by the Cambridge Botanical Supply Company, but had merely been reprinted by them from the pages of the *Bulletin*, and it seemed only reasonable that the Club under whose supervision the catalogue was prepared and first printed should also issue it in card form. The Card Index thus became the third series of Club publications.

Until 1900 it had been customary for the Club to hold all its meetings in the evening. The first meeting of May, in that year, however, was held in the afternoon at the New York Botanical Garden; the Club joined with Section G (Botany) of the American Association for the Advancement of Science in its celebration of "Torrey Day" at the Garden, June 27,* and after the summer vacation began the custom, continued until this day, of holding one of the two meetings each month at the Garden, and in the afternoon instead of evening.

The commencement of the new century was marked by several important changes. The *Bulletin* had grown until its annual volume comprised nearly 700 pages and many plates, and the pressure for publication of technical papers tended to exclude brief communications and those of a popular character. A new monthly journal was therefore established by a vote of January 8, 1901, under the editorship of Dr. Marshall Avery Howe, and the first number of *Torreya* made its appearance before the end of the same month. The following year the publication of the proceed-

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* The historical papers read on this occasion were published in the *Bulletin* (27: 540–565. 1900); the one by Professor Burgess on "The work of the Torrey Botanical Club" was prepared with much care, and contains various details of the Club's history which are not repeated here.

ings of the Club was transferred to *Torreya* from the *Bulletin*, but otherwise its scope as "a monthly journal of botanical notes and news" has remained unchanged under successive editors.

At the same meeting which authorized the establishment of *Torreya*, the Club voted to present its herbarium, subject to certain conditions, to the New York Botanical Garden; and at the following meeting the privilege long enjoyed by Columbia University of incorporating Torrey Club exchanges into its library was transferred to the library of the Garden.

Judge Brown's long term in the presidency was followed by the election of Dr. Henry Hurd Rusby, who held the office for the seven years 1905 to 1911. In spite of this comparatively long tenure, however, the tendency has been, perhaps more from accident than by design, toward rotation in office, and during the past twelve years there have been four presidents and five editors. I shall not dwell upon these later years, for many of my hearers have been familiar with their history and contributed in an important measure to it; moreover, it is so fully recorded in printed form that my omission of it need not embarrass the future historian. The expansion of the Club from a purely local association to a body of almost national scope can scarcely be emphasized, however, by anything more than the wide geographic distribution of our present active membership, and the fact that our main editorial office is now in New Haven and our editor a professor in Yale University.

About the beginning of the year 1905, the Club began to hold its evening meetings at the Museum of Natural History instead of the College of Pharmacy; and some two years later, upon the dissolution of the Scientific Alliance, the Club joined with the other members of the Alliance in becoming affiliated with the New York Academy of Sciences. Organic union with the Academy is not close, but the Club has a representative in the Council of the Academy, and the Club's meetings are announced in the Academy's weekly bulletin.

Time fails me, on an occasion like this, to refer in detail to the vast amount of valuable scientific work accomplished by members of the Torrey Botanical Club, and presented in our meetings or published in the *Bulletin*, the *Memoirs*, and *Torreya*. Nor have I found an opportunity to mention, even by name, the many who have devoted years of faithful service to the Club's interests, as vice-presidents, secretaries, treasurers, curators, librarians, associate editors, and members of important committees. Of one standing committee, however, I feel that I must speak.

The early work of the Club was, as already pointed out, largely in the field. At first Manhattan Island furnished many interesting localities for rare plants; but, with the growth of our metropolis, the wild conditions that so delight the field-worker were pushed farther and farther from the center of the city and with this increased inaccessibility and an accompanying diversification in the interests of the members came a decline in the field-activity of the Club. All through its history, however, the Club has clung to the idea that it was its duty to arrange field-meetings for those who desired to avail themselves of such a privilege. There have been times when the field-activities of the Club seemed on the verge of extinction; but always some one has been found to serve on the field-committee, and the present committee has in the past few years seen a renewal of interest under the stimulus of its efforts, particularly those of its chairman. May the Club never fail to retain a strong hold upon the soil from which it sprung!

REMINISCENCES

By Herbert McKenzie Denslow

The General Theological Seminary

The Rev. Dr. Denslow spoke somewhat as follows:

Mr. President and Fellow-Members of the Torrey Botanical Club: I am quite aware that I appear to-day as a relic. When I tell you that I attended early meetings of the Torrey Club while a school-boy in Brooklyn, you will readily understand that there will be little of scientific accuracy in my recollections of that distant time. That I was allowed to attend the meetings in the Herbarium at the School of Mines was due in part to the fact that my uncle, W. W. Denslow, was a member of the Club and in part to the great kindness of Dr. Torrey. I was present at the dinner on December 20, 1867, but I recall distinctly only that Dr. Gray was present, as well as Dr. Torrey, and that the occasion was most impressive to my boyish imagination. It was my first function of that sort and I probably exaggerate the number present; but my memory has always reported a long table and a goodly company.

It is to my uncle that I owe my introduction to botany. I made many field-excursions with him and his friends and worked in holiday times on his herbarium. My beginnings of botanical knowledge were thus practical and concrete. Whether there is pedagogical suggestion in this, I do not assert. Probably a certain intensity of interest and application, which is a family trait, contributed to my early enthusiasm. Certainly I gained a lifelong interest in the study of plants; and this avocation has not only contributed much of pleasure but has helped distinctly in shaping my mental life.

It was for little more than three years that I was able to attend with some regularity the meetings of the Club. Then college life in New Haven, followed by teaching and professional study, kept me fully occupied elsewhere. I bound up my few volumes of the *Bulletin* and found scant time for botany. Still I continued to collect and exchange, having inherited my uncle's duplicates and some of his correspondents, until my herbarium became too large to be lodged conveniently in a rectory. I sold it for a nominal sum to Hobart College, reserving only the Orchidaceae. But I continued to study this family, from time to time, in the midst of a busy parochial life. After being away from the vicinity of New York for more than twenty years, I came to my present position in 1902; and it was a great pleasure, after getting fitted to my new harness, to renew my active association with the Torrey Botanical Club. It is seldom that I can attend a meeting, but I have and read its publications; and you will readily understand that I get to the Botanical Garden as often as I can and that I find there always the kindest welcome from all whom I meet.

TORREY BOTANICAL CLUB REMINISCENCES

By Nathaniel Lord Britton

The New York Botanical Garden

I gladly contribute reminiscences of the years immediately following my election to the Club in 1877, while I was a student in the School of Mines, with especial reference to members of the Club known to me during that period.

Dr. George Thurber was president in 1877, and for many years afterward the meetings were held at the herbarium rooms of Columbia College, at 49th Street and Madison Avenue. Dr. Thurber, long editor of the *American Agriculturist*, had a fertile fund of botanical information of all kinds and stimulated discussion on nearly every topic presented at the meetings. Mr. P. V. LeRoy, who had been an assistant of Dr. Torrey, was curator of the Torrey Herbarium and he carefully guarded the collection during his incumbency and increased it by the purchase of many valuable sets of plants.

I entered the School of Mines in 1875. Dr. Torrey died in January, 1873. While I was being prepared for the School of Mines at the Staten Island Academy, I was taken on several occasions to Columbia College by my father to see Dr. Drisler, and on one of these visits I was told where the herbarium was located and a professor was pointed out to me as the renowned Dr. Torrey. This did not make much impression on me as a boy, but later, when becoming familiar with Dr. Torrey's portrait, I recollected the incident. Mr. J. J. Crooke, then resident of Great Kills, Staten Island, an all-around naturalist who accumulated large collections, induced my parents to send me to the School of Mines, and told me much about Dr. Torrey. Mr. Crooke was Treasurer of the Club for a period.

Mr. William H. Leggett, who founded the *Bulletin* of the Club in 1870, was still its editor; he was an enthusiastic field and herbarium botanist, a highly successful teacher, and a fine linguist who inspired all his associates. His herbarium forms the principal part of the nucleus of the Local Herbarium of the Club, which has in later years been expanded into the Local Herbarium of The New York Botanical Garden. Dr. Timothy F. Allen, a physician of prominence and a man of delightful personality, had already commenced his long-continued studies in Characeae, and was interested in obtaining specimens of these plants from all parts of the world. Mr. J. M. Wilbur, Secretary of the Club for many years, seldom missed either a field or an herbarium meeting. Dr. J. W. Barstow, resident of Flushing, was a frequent attendant at meetings and brought in many specimens. Mr. John L. Wall, an active microscopist, attended many field-meetings and subsequently was one of the founders of the New York Microscopical Society; I was closely associated with him for a period of years. Mr. William Bower, who had a garden of native plants at Newark, New Jersey, and was keen on their cultivation, rarely missed a field-meeting. Mr. W. R. Gerard, subsequently editor of the *Bulletin* and a man of great erudition, was pursuing his mycological studies. Messrs. Isaac Buchanan and James Hogg, both nurserymen, occasionally came to meetings and brought specimens of cultivated plants; Thomas Hogg, brother of James, joined the Club in 1882, after returning from Japan, whence he sent many Japanese shrubs and trees for their first introduction into the United States; he subsequently became a Vice-president of the Club and was active at its meetings; I saw a great deal of him in later years. Professor James Hyatt was already an enthusiastic microscopist, and I well remember collecting diatoms with him in marshy grounds now occupied by the systematic herbaceous plantations of The New York Botanical Garden. Mr. C. F. Austin, who resided at Closter, was in the midst of his important bryological work, but it was never my good fortune to meet him; after his death in 1880, Dr. Newberry sent me to Closter to buy his bryological collections, which thus became the nucleus of the great moss herbarium subsequently built up by Mrs. Britton at The New York Botanical Garden. Mr. M. Ruger was a regular attendant at all meetings and a diligent collector; a considerable number of his specimens are preserved in the local herbarium; one of the first field-meetings I remember was under his guidance at

Train's Meadows, Long Island, especially to collect *Scleria verticillata,* first found by him there in 1874. Dr. Denslow we still have with us; Mr. H. A. Cassebeer, Jr., will attend the dinner this evening.

Professor D. C. Eaton was vigorously pursuing his fern studies at Yale and sent communications for the *Bulletin;* I do not remember seeing him at any meeting, but I visited him at New Haven. Mr. G. W. Wright and Mr. William Chorlton, both of Staten Island, contributed much to the interest of meetings by bringing specimens of both wild and cultivated plants. Judge Addison Brown had already commenced his active participation in the affairs of the Club and his important influence on American botany by forming an herbarium, and for a number of years attended nearly every field-meeting. Mr. J. H. Redfield, of Philadelphia, made occasional contributions to the *Bulletin;* I do not think that he was ever present at a meeting which I attended, but I visited him later in Philadelphia. Professor Joseph Schrenk, almost our only plant anatomist and physiologist of those years, was at the Hoboken Academy and subsequently at the College of Pharmacy; he was a keen observer, and I recollect searching for *Schizaea* with him at Tom's River for a day without finding any, but he took in a sod of *Drosera* for experimental purposes, and shortly afterward found that he had *Schizaea* in the same sod! Mr. Cornelius Van Brunt was pursuing studies of diatoms and his collections subsequently came to the New York Botanical Garden; he was present at a number of field-meetings and helped found the New York Microscopical Society.

Professor Alphonso Wood, of the College of Pharmacy, resided at West Farms, where I once visited him with others of the Club and the party walked up the Bronx Valley through the whole length of the present New York Botanical Garden reservation, on which occasion I first saw the pot-holes, located near the west end of the present Boulder Bridge, which I described in the Transactions of the New York Academy of Sciences in 1881; it was this trip that gave me my first knowledge of the natural beauties of the Bronx Valley. Professor Wood had at that time about completed his long series of noteworthy text-books. Dr. O. R. Willis, a diligent student of the local flora, resided at White Plains and attended many meetings of the Club, contributing notes and specimens. Dr. L. Schoeney, a practicing physician, was in those years perhaps the most constant attendant at both field and herbarium meetings, and continued his interest over a long series of years. Dr. Arthur Hollick, who was elected in 1877, at the same time I was, is one of the few living persons who has maintained continuous membership in the Club since that time; he was active with me in the study of Staten Island plants and our collections of those years are preserved in the herbarium of the Staten Island Association of Arts and Sciences.

Dr. Newberry, then in the midst of his paleobotanical studies, occasionally came to the meetings, being elected to membership in 1878, and became President to succeed Dr. Thurber in January, 1880. He had an enormous fund of botanical information and was able to throw light on almost every topic brought up for consideration; as his assistant in the School of Mines for a series of years subsequent to 1879, it was my good fortune to be closely associated with a naturalist of his renown. Miss Elizabeth G. Knight (subsequently Mrs. Britton), elected in 1879, had already absorbed enthusiastic interest in plants and animals, through association with Dr. Newberry and with Professor Edward H. Day, of the Normal College, who was elected to the Club in 1880 and who subsequently participated in many field-meetings. Professor Day was a most jovial naturalist, a pupil of Huxley, and of very broad information. He led a field-meeting once into Monmouth County to see *Lygodium*, and perpetrated a pun in wanting to know why that tramp was like rum, which he expounded by maintaining that it was a sandy cruise (Santa Cruz)! As a popular professor of the Normal College, Professor Day is remembered with affection by a large number of students. Mr. Eugene P. Bicknell, who was elected in 1880, had already commenced his critical studies of the local flora, especially of what is now the Borough of the Bronx, and had begun the formation of his extensive herbarium; he attended herbarium meetings with much regularity and contributed frequent notes and specimens. Mr. William H. Rudkin, subsequently and for many years Treasurer of the Club, became a member in 1878, and for a long period contributed important aid to the work of the organization, attending both field and herbarium meetings and aiding Mr. Leggett in the publication of the *Bulletin;* both Mrs. Britton and I were with Mr. and Mrs. Rudkin much during those years.

My first botanical contribution was made to the Club in September, 1877, and printed in the October *Bulletin* of that year; it is upon Rarer Plants of Staten Island, including a note on the sensitive stamens of the *Opuntia* of what is now Crooke's Point. Was this a premonition of my subsequent interest in Cactaceae?

TORREY BOTANICAL CLUB REMINISCENCES

By Arthur Hollick

Staten Island Association of Arts and Sciences

If I remember correctly, it was in 1876 or 1877 that Doctor Britton and I joined the Torrey Botanical Club. We were classmates in the Columbia College School of Mines at the time and had collected plants together in a more or less desultory way. Each of us had a small local herbarium and we did the best we could to identify and name our specimens with the aid of Gray's Manual. The only instruction we received in botany was one lecture a week during one term, by Professor Newberry, who also lectured on zoölogy, paleontology and geology. Practically, he was professor of "natural history." There was no laboratory work of any kind and we were left entirely to our own devices so far as assistance in securing botanical information or knowledge was concerned.

We had heard vague rumors to the effect that somewhere in the recesses of the old college buildings an herbarium was housed, and after making several inquiries we finally located it, and found Mr. P. V. Leroy in charge as curator. I believe his salary was paid by Mr. John J. Crooke and not by Columbia. Certainly Columbia made no use of the herbarium. The Torrey Botanical Club met there and in this way we became acquainted with some of the members and soon ventured to apply for admission.

I shall never forget the first meeting I attended. I felt that I was under indictment for the crime of being a young man. There were no young botanists in those days. Many of those whose acquaintance I made at these early meetings were as old as I am now and others were older, and that was forty years ago. I recall particularly Alphonso Wood, William H. Leggett, P. V. Leroy, O. R. Willis, Bowers, Ruger, and several others. I never met Dr. Torrey, of course, as he died in 1873. No woman had yet been elected to membership in the Club. Any such innovation would have been unthinkable at that time. We brought specimens to the meetings, discussed them, helped each other to identify them, described how, when and where they were collected, and then arranged informally for a field-meeting—perhaps for more than one—before the next meeting of the Club. If I remember correctly the dues were one or two dollars a year. Subscription to the *Bulletin* was a dollar. It was not published by the Club, but by Mr. Leggett personally. There were no expenses, except in connection with the small number of postal cards to announce the meetings. The money in the treasury was mostly spent for refreshments, and after each meeting we had a pleasant, sociable time, drinking coffee and eating cakes and sandwiches and occasionally fruit when in season.

Attending meetings in those days was not so easy as it is now—I mean for out-of-town members. I lived at Port Richmond on Staten Island. The last boat to the island was at 9 P. M. I used to take the midnight train on the Central Railroad of New Jersey at Liberty Street, get off at Bergen Point Station, walk three quarters of a mile to the shore of the Kill van Kull, wake up a man who lived in a little shanty there, and hire him to ferry me over to Staten Island in a rowboat, arriving home about 1:30 A. M. Sometimes, in winter, the trip was not a comfortable one; but I do not recall that I ever thought it a hardship, and, to the best of my recollection, I think I merely regarded it all as a matter of course.

I still live on Staten Island, but I can attend this meeting in the Bronx to-day far more easily and with less waste of time in coming and going than was formerly the case when I attended the meetings held at 49th Street.

A SKETCH OF THE LIFE OF COE FINCH AUSTIN

By Sarah Austin Demarest

Englewood, New Jersey

Coe Finch Austin, the subject of this sketch, was born June 20, 1831, at Finchville, Orange County, New York. Grandparents on father's side were Abraham Austin, English descent, and Mehitable Campbell, Scotch, and on his mother's side, William Cortright and Jemima Huff, both Hollanders. He was the second of a family of ten children, born to James C. and Elizabeth Cortright Austin, thrifty farmers of that period. When he was quite young his parents moved to Greenville, N. Y., where the lad entered the public school. He made rapid progress in the fundamentals. A few years later the family moved to a fine farm near what was then called Brookfield, now Slate Hill, Orange County, N. Y., where his early life was spent, much the same as other boys, assisting on the farm during the summer, and attending public school in the winter, where he was generally at the head of his class and at the forefront in the various games played on the school grounds.

Early in life he manifested an interest in floriculture, and was his mother's constant companion as she cared for her flower garden (of which she was extremely fond), this same being often enriched by choice specimens which the boy gathered from neighbors of like tastes. Nor was he less interested in arboriculture, and the lawn of his paternal home was ornamented by trees of many varieties collected from forest and field, whose generous shade now gives pleasure and comfort to another generation occupying the homestead.

In character he was independent and aggressive, and impatient of restraint. When about eighteen years of age, being reprimanded by his father for some neglect of duty, he rebelled, and as a result was compelled to take the world for his parish; he went through the full experience of the "Prodigal Son," returning after a few months, if not a sadder, a wiser boy. He partook of the fatted calf with evident relish, and there was joy in the household again, there being no elder brother in evidence to mar the occasion. This experience wrought a wholesome change in his character; he cut off some of his old companions, and started life on a new track. Soon after this he took up teaching and lecturing in neighboring schools during the winter months.

In the early 50's he entered Rankin's Classical School, at what is now Sussex, in Sussex County, New Jersey. Here he met a congenial spirit in the person of Mrs. Rankin, a botanist of some note, and to this chance meeting his choice of life work is undoubtedly due. He came from this school a working botanist. At first he took up the subject in its broadest sense, but after a time realized that the field was too broad to accomplish much in a lifetime, and becoming infatuated with microscopic revelations, he dropped all except mosses and lichens. In his search for specimens of them he was most indefatigable, letting no obstacles, however formidable, deter him from their pursuit. No distance was too great, no jungle too dense, no mountain too high or steep, no toil too great, to turn him aside in his eager search for new forms. Accompanied by an Indian he would spend whole days in the forests and field, from early morning till night, with no other food than berries and roots, which his knowledge of botany disclosed as of food value. He was heard to say that the botanists have sources of food supply that the world knows not of.

During the winter of 1856–57, in company with Edward Swift, of Marathon,. N. Y., he toured New England, lecturing on electricity and chemistry, with apparatus to illustrate, and it was said by those competent to judge that his brilliant experiments were the most striking of their kind, and rarely, if ever, surpassed by any one. He was heard to say that if man ever learned to control electricity of sufficient power they would see horseless carriages and the steam engine would be succeeded by electric engines.

Later, in 1857, he accepted a position as school teacher at Tappan, N. Y. There he met Hannah Campbell, daughter of David P. Campbell, a farmer, living on the Alpine Road, about one quarter mile from Closter, N. J., to whom he was married, May 11, 1858. In the fall of that year he went to Dennisville, Cape May County, N. J., taught school for a year, and it was while there that he met in his wanderings through woods and marshes Charles F. Parker, of Philadelphia. In the early days of their acquaintance the latter often visited him, and it was he who assisted him in the purchase of his microscope.

Miss Warwick, a resident of Dennisville at that time, told the writer a few years ago that she had vivid recollection of the lectures delivered in her town by Professor Austin. He drew large gatherings of people from the surrounding country, for the subjects were new to them, and his experiments were always very successful, which made the lectures attractive.

In the middle of June, 1859, he, with his family, returned to Closter. About this time he became acquainted with Dr. Torrey, and through Torrey's influence became curator of the Columbia College Herbarium. He moved, in the autumn of 1861, to an apartment in the college. During this period he devoted himself to intensive study; his power of concentration was remarkably great. He remained at the college until after the spring of 1863, when he again returned to Closter, again taking up lecturing, going through the country for miles around, traveling with a little pony and a carry-all wagon.

In 1865 and 1866 he taught school at Demarest, N. J., one mile south of Closter, and spent his noon hours in nearby woods, gathering mosses and other plants, which he often showed to his pupils, pointing out and explaining the peculiarities of each. Boys of neighboring villages were always on the lookout for him, and, when spied by one, soon there would be a group of them around him, for his pockets always contained something to interest them. Those were days when children were not noticed by grown-ups, as they are to-day, and the attention he paid to them was very acceptable.

As a teacher he was fond of children, and if they could not keep up with their classes and showed a willingness to do so, he would help them after school hours, but he had no patience with those who could be termed lazy.

His last lectures were delivered at the Englewood Institute in the winter of 1871–72. His interest in botany increased as time went on, possibly due to his finding new species of mosses, hepatics, and lichens. Some time in the latter half of the 60's a piece of swampy meadowland, lying due west of what was then the Reformed Church Parsonage of Closter, had been cultivated and seeded down by a neighbor living a little distance away. One day the pastor's little daughter came rushing to her father excitedly, saying a man was stealing Freddie's turnips. Rev. Hammond, for that was the pastor's name, went out to see who the intruder was. He saw him on his knees, scraping earth with his hands. As he came near he found it to be the botanist, who joyously exclaimed, "I have found a new lichen." He walked with his friend up to the parsonage, telling about his discovery as they went. When he reached there he was bubbling over, and he asked Miss Isabelle, who had caught some of his enthusiasm, what he should name it and she replied, "Austini." It was this pastor who assisted him in his study of classical Latin, but he had to study out botanical terms without assistance. He maintained a large correspondence with scientists in all parts of America and Europe, his knowledge of Latin being a benefit to him, but desirous of corresponding with a noted German botanist, and being ignorant of the language, he laid aside everything until he had so far mastered it that he was able to communicate with this person.

Many specimens were sent to him to be named, from foreign countries as well as the United States and Canada, in which he was so intensely interested that with his beloved microscope he would work until two or three o'clock in the morning, seeming oblivious of the passing of time, God giving him to see in the humble mosses and lichens which the world tramples under foot oceans of beauty and interest. He seemed to have a contempt for the riches of this world, his gold mine being the dense forest or the rugged mountain, rich with his beloved mosses.

I recently received a letter from Dr. J. J. Haring, of Toledo, Ohio, formerly of Tenafly, N. J., an old friend of his, still living, from which I quote the following: "I remember many conversations with your father in his best years—upon botanical matters, especially in relation to that of mosses, of which he was a close and enthusiastic student, devoting to them most of his time, of years not a few. I remember his pride in having the opportunity of correspondence with leading authorities on mosses, and his exchange of rare specimens of them. Especially do I recollect his enthusiastic announcement that he had discovered varieties unknown to writers and students in his particular line. . . . Had his life been spared for some years longer, and could he have been more favorably situated financially, it is my belief that as an authority on mosses and lichens he would have been surpassed by only a few distinguished specialists in his chosen department of botanical work and study."

Many positions of profit were offered him, but all were rejected for fear that their acceptance would interfere with his favorite study, ignoring the fact that his family would be benefited thereby, yet no one who knew him would think of calling him selfish, for his knowledge of any subject was theirs for the asking.

He made the most of every day allotted to him, but not always, in fact seldom, for his own benefit. He was kind-hearted, and always ready to give a helping hand to those who needed his assistance, invariably without remuneration. He was happy, and fond of his family, proud of the progress made by his children in their studies, never refusing, no matter how busy, to help them over difficult problems.

He accepted his circumstances uncomplainingly, for he was so infatuated with the love of nature in all forms that if he could study unmolested he knew no cold, heat, fatigue, or hunger. Family needs, trials, and troubles he left for others to care for. He was of a cheerful disposition, and could always find something to smile about, often on account of the clumsy way some one tried to do a piece of work, for he could mend a plow, or repair a watch, as well as any one.

During the last decade of his life he would leave his studies and make excursions into the country on foot, in search of specimens. To illustrate his intrepidity and fearlessness on these excursions, the following incident may be given: While visiting a brother at Haverstraw, N. Y., he expressed a desire to ascend the "High Tor," a rocky and precipitous eminence of the mountain, setting back landward near the town. This peak rises to a height of about 800 feet. Its front is rocky and rises in a succession of sheer faces of from 25 to 50 feet. A rugged path called the "Deer

Path" affords a comparatively easy means of ascent, the difficult places being bordered by scant shrubbery, which being grasped by the hands enabled one to ascend. Here and there on the way up specimens were added to his shoulder-bag. On reaching the top, and after viewing the magnificent scenery, he surprised his brother by handing him the specimens, with instructions to meet him at a certain point at the base of the mountain, saying that he would descend the face of the peak. The brother was horrified at the suggestion and tried to dissuade him from so hazardous an undertaking, but failed. Arriving at the point of meeting agreed upon, no sound of his approach could be heard, and no answer was made to his brother's vociferous call. An approaching thunderstorm added to the brother's apprehension of disaster. Suddenly the botanist appeared, loaded with specimens, and a smile on his face which was intended to convey a rebuke for faint-heartedness.

In 1870 he began the task of mounting in book form his Musci Appalachiani. This work was carefully and artistically done. One who did not see the work being done could not possibly form any idea of the amount of time and painstaking labor required to arrange each set.

At this time Closter was rapidly building up, and owners of new homes were desirous of beautifying their grounds with shade-trees, but met with much disappointment because so many of the trees died. He, being successful in planting trees and shrubs, was asked by a neighbor if he would take up the work. He felt sure of success, and in a modest way began the work, selecting his trees from woods of the farmers on the outskirts of Closter, until the demand was so great that he started a nursery. The beautiful shade-trees stand to-day as monuments to his memory. It was he who brought pond lilies to this region and planted them where-ever he found suitable place for them. No matter how hard he worked during the day he was always ready to handle mosses in the evening.

He took several trips in the interest of botany. He went to Ohio to see Mr. Sullivant, and to the White Mountains, his last trip being to Florida. There in a rowboat, with a negro oarsman, he ransacked the banks of southern rivers and morasses, looking for new treasures. He enjoyed remarkably good health until the southern trip, for there he contracted a sort of malarial fever, which undermined his health, and he seldom visited his familiar haunts on the Palisades after that.

The last time he went there was to meet a prominent man at Col. Miles's. He wore a new suit, just completed by his wife, and much against her wishes, for she knew his failing, but he promised her he would not go botanizing, simply going for a call. On his return he was tired, and stopped at his father-in-law's to rest, looking more like a tramp than the gentleman of a few hours before, and behold he had cut the lining of his coat and used his coat for a bag to carry mosses—he had found such beautiful specimens that he could not pass them by!

Although for several months he gradually grew weaker, he did not give up his work entirely, for he realized he was near the end of his life's journey, and was anxious to complete the arranging of several sets of his supplement to Musci Appalachiani, so that they could be disposed of profitably by his family. He continued until he was getting the numbers mixed because his mind could not endure the strain, laying the work aside, unfinished, three days before his death.

On March 18, 1880, he was called from the scenes of toil and study. His parents, then residing in Ridgebury, two miles from Slate Hill, being too feeble to come to Closter, appropriate funeral services were held in the Ridgebury Methodist Church, and interment was in the family plot in the cemetery adjoining the church. He left a widow and six children, one son and five daughters, the youngest being then seven years old. His widow was called to her rest December 12, 1916. The six children are still living. They are all married.

Sarah Elizabeth, wife of Abraham Demarest, Englewood, N. J.
David C. Austin, of Westfield, N. J.
Annie, wife of Walter G. Warner, of New York.
Kate, wife of Henry Scott, of New York.
Marietta, wife of Harry L. V. Warner, of Bloomfield, N. J.
Ella, wife of Edward W. Dorey, of New York.

Large quantities of mosses continued to come to his address for fully two years, the senders not knowing of his decease. Five years later, the minister who officiated at his funeral, while traveling on pony-back over the Rockies, alighting to take a rest, found a man gathering mosses. As he was in a measure interested in them he opened up a conversation with him in regard to what he was collecting, and much to his surprise he found him to be an amateur, who expected to send his unfamiliar varieties to Professor Austin of Closter, N. J., to be named. Our friend told him there was no Professor Austin in Closter, whereupon he insisted he had the name correct and that our friend was mistaken, until told that such was the fact, as our friend had officiated at the funeral.

Mrs. Isabelle Hammond Demarest, of Closter, N. J., whose name has been mentioned before, a neighbor of Professor Austin's, who had known him since the early 60's, caught his spirit, and after reading this sketch insisted that the writer was not nearly enthusiastic enough in her portrayal of her father's life. While that may be true, the respect and veneration which the writer has for her father's memory will not permit her to record a single statement which she does not know to be based upon solid fact. His unostentatious character has been to a certain extent reproduced in his daughter, and so she has recorded merely the ground-work. Let the laudatory trimming be added by some other hand!

RECENT BOTANICAL COLLECTING IN THE REPUBLIC OF COLOMBIA

By H. H. Rusby

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There are three reasons why the flora of Colombia is of exceptional interest to students of plant distribution:

A. This country contains what might be called the "elbow" of the Andes mountains; the region where their northern extension is exchanged for a broad sweep to the east along the Caribbean Sea.

B. Soon after entering southern Colombia, the Andes divide like the tines of a fork, into three parallel branches. Since these three ranges are of very considerable height and a large part of their intervening valleys is elevated but little above sea level, there results an extreme range of climatic conditions, with a corresponding diversity of flora.

C. The country yields a number of important drugs, besides many other economic products of great interest and value.

Although the Colombian flora has been much studied, this study has been rather fragmentary than general and we have yet a great deal to learn regarding the relations between its different parts. Among the noted botanists who have studied and collected there, are Humboldt, Zea, Mutis, Triana, Karsten, and Caldas, in former times. During the eighties, Lehmann collected very extensively in the south and west. More recently, many small collections have been made, especially by American botanists, besides quite an extensive one by Mr. Herbert Smith, in the vicinity of Santa Marta.

My personal interest in the study of this flora is of a rather exceptional character, because of the great amount of work that I have done upon the flora of neighboring portions of the Andes. In 1885, I made very extensive collections from Peru southward to Chile, later traversing the entire length of the Madeira and Amazon Valley. Thereafter, I maintained a collector in Bolivia for several years, and more recently still have been receiving collections from the Bolivian Department of Agriculture. During the nineties, I spent a season collecting in the lower Orinoco region. All of Mr. Smith's collections are represented at The New York Botanical Garden, as well as most of those of Dr. Lehmann. There was thus left an Andean region, occupying most of Colombia, the flora of which I had not seen and I have for many years desired greatly to visit it. This desire was increased by reason of my special interest in medical botany.

During the past season an opportunity was afforded for gratifying this desire, when I was asked to go to Colombia and investigate certain of its drug supplies. Although the work to be performed was of a commercial character, an opportunity was afforded for extensive botanical collecting, and I brought back with me some thirteen hundred collection numbers. This collection was principally the work of my associate, Dr. Francis W. Pennell, of the Garden staff, who accompanied me.

We left New York on June 27 and I returned on September 29, so that the entire journey occupied a period of three months and two days. Almost immediately after reaching the Port of Colombia, we boarded a river steamer and ascended to the head of steamer navigation on the Magdalena River, a journey which occupied more than a week. It thus happened that all but fifty-one days of our time were spent in sailing, when little or no collecting could be done. Quite a number of plants were collected along the river shore, when the steamer was making prolonged stops for taking on fuel, or for discharging and receiving freight. Since the vessel was close to the shore during most of its sailing, there was good opportunity, by the use of the field-glass, to ascertain the character of the neighboring vegetation. Because of my previous familiarity with tropical American plants, I was enabled to utilize this opportunity to excellent advantage.

On leaving the steamer at Girardot, we traveled by mule directly southward for seven days, getting pretty well up on the table-land adjacent to the upper Magdalena Valley. We next secured fresh mules and proceeded eastward, just crossing the ridge of the eastern range. About a week was spent in collecting about the summit of this Cordillera. We then returned north to Girardot and took railroad train to Bogota. Circumstances interfered with collection work during my stay at this city, but Dr. Pennell, then and subsequently, did a large amount of work within a radius of two or three days' foot travel from the city. At Bogota, we separated, I returning north to visit the western mountains, while he descended to the great plains where the tributaries of the Orinoco and Negro Rivers take their rise. At Puerto Berrio I left the river and crossed the central range, where several days were spent. I had intended descending the Cauca River and possibly getting over into the valley of the Sinu, but adverse circumstances forced me to change my plan.

Inasmuch as not even that part of the collection received here has yet been studied, it will be seen that only the most general statements regarding the flora can be made. Arrangements have been made by which Dr. Pennell is to remain for several months in Colombia, visiting and collecting in districts where little botanical work has been done. It is to be expected that his collections will be very rich and that their study will add greatly to our present knowledge of the Colombian flora.

The Magdalena River flows through a broad, low, flat valley for at least half of its length. From the steamer, the mountains can be seen in the distance on both sides during most of the time. As we start our journey from the mouth of the river, we can see, near Santa Marta, the snowy summit of the highest peak in Colombia, said to have an altitude of more than twenty thousand feet, The river plain is covered with tall and luxuriant grasses, as well as sedges, and affords excellent grazing. The cattle industry here is large but is not a tithe of what is possible with an abundance of labor and economic methods. A great drawback to this industry is the extent to which young cattle are destroyed by the annual freshets, which occasionally inundate almost the entire plain. The most conspicuous features of the flora here are magnificent palms (called "palma real" by the people, and yielding very important useful products), bamboos, and pampas grass. Up to the time of this journey I had regarded the tree fern as being the most beautiful representative of the vegetable kingdom, but I am now disposed to accord this place to the bamboos of the Magdalena Valley. I can compare one of them to nothing more fitting than a very fine ostrich plume. Their shape and their method of drooping is exactly the same, and when one finds a cluster of them, with the individual fronds arching over from the center, the effect is indescribably handsome. The pampas grasses also present a lovely appearance. The entire flower stalk may reach a height of twenty feet or more. Its lower two-thirds is very leafy. Then there is an elongated bare peduncle surmounted by a panicle several feet in length. The branches of this panicle are exceedingly long and slender, so that the slightest breeze is sufficient to blow them out in a horizontal position at one side, giving a remarkably close imitation of a flag. The color of this flag ranges from light pink to a rather dark purple. All travelers are captivated by the beauty of this grass, which grows in patches, rarely of any great extent, throughout the entire river valley. The clumps of shrubbery that are scattered over the plain belong very largely to the *Mimosa* family, especially in the lower part of the valley. As we ascend, other classes mingle with them and they become very much more abundant and larger, at length giving way to a heavy forest growth which extends quite to the river's edge. In this region, especially after we reach the hilly section, the river bank is gay with Heliconias of several species. The inflorescences are of a brilliant red, largely variegated with bright yellow, and to a lesser extent with blue. Those of one group are strictly erect, with slender stiletto-like branches, while those of another are pendulous, several feet in length, and of a regularly sinuous form. Throughout the greater length of the river, the trees near the water are largely Cecropias, of a number of species, and are of very striking appearance. Some have simple trunks, their huge digitate leaves on very long petioles, and radiating directly from the summit to form an umbrella-shaped crown, while others have a few loose and open branches. The trunks and branches of all are very light colored, appearing whitish at a distance when the sun strikes them. Most of them have hollow stems and branches which are inhabited by colonies of fiercely stinging ants. Back of these "*ambaibas*" comes a growth of Ceibas or silk-cotton trees, which are even more conspicuous, and are stately in their beauty. These trees have tall, straight trunks, without branches until after they have surpassed the trees around them. Usually there is a conspicuous and graceful enlargement of the trunk at one or more points. The branches are almost horizontal and often of great length, while the crown is flattened, thus giving them a peculiar parasol-like appearance.

There are many Bignoniaceous vines, but they are scattered, this being one of the most conspicuous differences between this and the shore flora of the lower Orinoco, where there is often a continuous curtain, miles in length, of brilliantly blooming vines of this family.

As we ascend the river, the mountain ranges on both sides steadily approach the shore. Every now and then the river will take a wide sweep and impinge against the foothills of the mountains, now upon one side and now upon the other. At such places we can distinguish no characteristic difference between the composition of the flora upon the two sides. This flora is very rich and varied, so that one can scarcely attempt a description of it. Ingas, Pithecolobiums and other related plants are freely represented. There are also many Cassias. Toward the upper part of the river, Acacias become the most conspicuous trees. When we go ashore, we find Zanthoxylums quite abundant among the shrubbery, together with Muntingias and other shrubs and small trees belonging to the Malvaceae and Tiliaceae. Clitorias are very numerous and very handsome. Rubiaceous shrubs, herbs, and small trees are exceedingly abundant, as are herbaceous Euphorbias and shrubby Crotons. Shrubby and arborescent Solanums are in bewildering variety. Large cactuses are seen occasionally in the lower river valley and become more and more abundant toward the highlands. They are, however, never in great variety and never so abundant as to be a very conspicuous feature of the landscape. Crotons and Solanums also increase in variety and abundance as we go southward, up the river.

In the vicinity of Girardot, the land has been mostly cleared of its forests, and we have an excellent opportunity to study and collect the flora of these open hills and fields, exposed to the baking of an extremely hot sun and generally known as "*pajinales*." Malvaceous and Tiliaceous shrubs, twining herbaceous Leguminosae, Zanthoxylums, Borrerias and related Rubiaceae, and especially Crotons and Solanums cover these grounds. There are very many sedges and in the more barren places, large areas clothed with Andropogons. Beautiful aquatics are found wherever the soil is suitable.

Leaving the steamer and traveling by mule, we rapidly climb to the dry table-lands near the base of the mountains and at places are obliged to cross projecting mountain spurs. In the lower places, we are impressed by the beauty of hedges of *mata-raton*, a small tree related to *Robinia* and handsomely covered with rose-purple panicles of flowers. Upon this part of the journey, we find great numbers of shrubby and herbaceous vines belonging to the milkweed and dogbane families. We crossed during the height of the dry season so that there was almost no collecting to be done, but it was quite evident that at certain seasons the flora of this mesa must be exceedingly rich and wonderfully beautiful. Among the grasses, Boutelouas are the most conspicuous. Water was scarce at this season, so that cattle and other domestic animals were forced to confine themselves to the narrow strips along the rivers and quebradas. As a result, these places were very much over-run and their flora largely destroyed. The shrubby and arborescent vegetation of these ravines and smaller river valleys consists largely of Acacias, among which are many cactuses, so that travel among them is very difficult. Large shrubby and arborescent Crotons and Solanums here continue to maintain a prominent position.

At length we are so fortunate as to be able to leave the prostrating heat, filthy odors, and mosquito- and malaria-infested valleys of the mesa, and to plunge among the ravines and canyons of the eastern mountain range. No sooner does one enter one of these valleys than he finds a rich forest growth, maintained at all seasons by the streams which flow upon or close to the surface of the earth. The composition of this flora bears a general resemblance to that of the remainder of the Andes. Its chief interest will center in the mixture of genera and species respectively peculiar to the south and east, and cannot be discussed until our collections shall have been studied. Crotons maintain the supremacy at the lower altitudes, while Solanums persist for a great distance farther up. We see many large areas on the open hillsides that are covered with a tall and stout *Andropogon* of a deep rusty-red color. Prominent and beautiful are one or more species of *Securidaca*, Polygalaceous woody vines which drape many trees with an unbroken canopy of pink or rose purple. Orchids and bromeliads are increasingly abundant as we approach the summit and many of them are very beautiful. No sooner do we begin to approach the summit than we encounter blackberry thickets, and these become more than conspicuous to the very summit. Of these there are many species and very possibly many hybrids, so that it is difficult for one to keep track of his collections. The canes are very tall and heavy, and in many cases assume a half-climbing condition among the trees. Their panicles of fruit are sometimes a foot in length and almost as broad at the base, and very dense, so that they droop heavily over the shrubbery. The individual fruits are sometimes more than an inch in length and breadth and their drupelets of surprising size. These larger varieties are scarcely edible, being sour and somewhat bitter, and reputed as poisonous. Others are of delicious flavor and are largely marketed. There is a strawberry with very small, extremely deeply pitted and rather poorly flavored fruit, which is also considerably marketed. The false strawberry forms large patches, which are brilliantly and temptingly fruited. Many of the timber woods are of great utility and value, especially a species of black walnut which is largely employed in cabinet work. Among the more beautiful flowers of the summit are Gesneriaceae, in great variety and of lovely shades, many terrestrial and arborescent orchids, several species of Fuchsias of exquisite beauty, Begonias and *Oxalis* of numerous species and several Fagelias. The handsomest flower here, and one of the handsomest that I have ever encountered, is a species of *Bomarea*. It climbs to a height of several yards, its flowering tops and branches then drooping deeply over the banks of verdure that line the trail. The flower clusters are often large enough to fill a peck measure and are of a rich maroon color, sometimes almost as deep as chocolate, at others of a rich crimson. The bell-shaped flowers are richly mottled in the throat and the effect is too handsome for description. This species has large tuberous roots which can be used as food. Dahlias are quite abundant and we are astonished to find one species forming clumps fifteen feet or more in height and more like small trees than herbs.

We are more than astonished to see *Physalis peruviana*, which with us is but a few inches in height, there reaching a height of seven feet and spreading equally in breadth, and capable of yielding a half bushel or more of fruit. Melastomaceae are quite varied and abundant, and rather beautiful, but cannot compare in this respect with the representatives of the family in the more southern countries. There are one or two species of *Befaria*, having the same habit of growth as our Azaleas and much resembling them when in full bloom, which are exceptionally beautiful features of the landscape, their color shading variously through pink, purple, lavender, and violet. Ferns are in great variety but not so handsome as in other parts of the Andes which I have visited. To this statement, we must except the tree ferns, which are abundant and lovely.

It remains to be stated that Vacciniaceous plants are abundant and diversified and many of them decidedly showy. For the most part, they bear scarlet or cherry-red tubular flowers in large and dense clusters, at the ends of long pendent branches. A number of them produce delicious edible fruit, one closely filling the place of our cranberry, but sweet and of better flavor. Ericaceae are also quite numerous, especially in swampy regions at the summit, but not nearly so conspicuous or beautiful as those of the family last considered.

There is one important feature of the climate here which it seemed to me might well be taken into consideration by those who endeavor to grow in temperate houses the plants of such so-called temperate regions as those under consideration. A "temperate" climate at these high altitudes is fundamentally different from a temperate climate at a lower altitude and farther north, even though the average temperature may be the same in both cases. In such elevated regions, among tropical mountains, the temperature regularly falls at night, even in the midst of the summer season, to a much lower point than is experienced in temperate latitudes. On the other hand, during the sunny portions of the day, we find it extremely hot, so that the variation between midday and midnight is extreme. It is not conceivable that plants which have been developed and which have lived under such conditions should not have acquired a constitution which requires such sudden and wide changes for their life and health. It occurred to me while experiencing these conditions that some instructive experimental work might be done by removing those plants to conservatories and subjecting them to various conditions of temperature, among others the changeable ones under which they have been accustomed to grow, and to compare the results upon their life history.

COLLECTING FUNGI AT DELAWARE WATER GAP

By William A. Murrill

The New York Botanical Garden

The writer's first acquaintance with the region about Delaware Water Gap was made on the Decoration Day excursion of the Torrey Botanical Club, May 29–31, 1917, a brief account of which appeared in *Torreya* for August, 1917. At that time, with the help of other members of the Club, 81 species of the more conspicuous fungi were collected.

Attracted by the variety of soils, exposures, and host plants which this region affords, I spent also a vacation of two weeks there, August 1–15, 1917, and secured a fairly representative collection for that season of the year. I hope some time to be able to secure the autumnal species. My collections to date include about 200 species, most of which are to be found in the following list.

The abundance of a species is indicated by exponents, the numerals *1–5* denoting a definite number of times collected and the letters *n*, *nn*, and *nnn* meaning "frequent," "common," and "very common," respectively.

A. ASCOMYCETES

Daldinia concentrica^2
Dothichiza populea^1
Endothia parasitica^{nnn}
Helotium citrinum^1
Helvella lacunosa^1
Hypomyces hyalinus^2
Hypoxylon coccineum^1
Lachnea scutellata^n
Leotia lubrica^1
Macropodia fusicarpa^1
Morchella esculenta^n
Orbilia chrysocoma^1
Peziza badia^1
Phyllactinia suffulta^n
Plasmopora viticola^1
Sarcoscypha occidentalis^2
Xylaria Hypoxylon^2
Xylaria polymorpha^1

B. UREDINALES

Allodus Podophylli
Gymnoconia interstitialis
Gymnosporangium effusum
Gymnosporangium germinale
Gymnosporangium globosum
Gymnosporangium Juniperi-virginianae

Gymnosporangium Nidus-avis
Nigredo Caladii
Nigredo Houstoniata
Polythelis fusca
Puccinia Impatientis
Puccinia Osmorrhizae
Puccinia urticata
Puccinia Violae
Transchelia punctata

C. HYMENOMYCETES

(*a*) Tremellales

Exidia glandulosa[2]
Tremella lutescens[2]
Tremellodon gelatinosum[1]

(*b*) Dacryomycetales

Calocera cornea[n]
Guepinia spathularia[1]

(*c*) Agaricales

1. Thelephoraceae

Craterellus cornucopioides[2]
Lachnocladium Micheneri[n]
Lachnocladium Schweinitzii[n]
Peniophora cinerea[n]
Stereum complicatum[n]
Stereum frustulosum[1]
Stereum hirsutum[1]
Stereum lobatum[n]
Thelephora multipartita[1]
Thelephora regularis[1]

2. Clavariaceae

Clavaria coronata[n]
Clavaria cristata[3]

3. Hydnaceae

Hydnum ochraceum[1]

4. Xylophagaceae

Gloeoporus conchoides[1]

5. Polyporaceae

Bjerkandera adusta[n]
Cerrena unicolor[n]
Coltricia cinnamomea[2]
Coriolellus sepium[1]
Coriolus abietinus[1]
Coriolus molliusculus[1]
Coriolus nigromarginatus[n]
Coriolus versicolor[n]
Daedalea confragosa[n]
Daedalea quercina[nnn]
Elfvingia fomentaria[1]
Elfvingia megaloma[n]
Ganoderma Tsugae[n]
Gloeophyllum trabeum[1]
Hapalopilus gilvus[n]
Hapalopilus rutilans[3]
Hexagona alveolaris[1]
Hydnoporia fuscescens[n]
Irpiciporus lacteus[nn]
Irpiciporus mollis[1]
Lenzites betulina[1]
Polyporus elegans[n]
Polyporus Polyporus[1]
Poria medullapanis[1]
Poria vaporaria[2]
Poronidulus conchifer[n]
Pycnoporus cinnabarinus[1]
Pyropolyporus igniarius[1]
Tyromyces chioneus[3]
Tyromyces lacteus[1]
Tyromyces semipileatus[3]
Tyromyces semisupinus[1]
Tyromyces Spraguei[n]

6. Boletaceae

Ceriomyces communis[n]
Ceriomyces crassus separans[1]
Ceriomyces viscidus[n]
Fistulina hepatica[2]
Strobilomyces strobilaceus[1]
Tylopilus felleus[1]

7. Agaricaceae

Armillaria mellea[1]
Chanterel cinnabarinus[n]
Chanterel minor[3]
Clitocybe infundibuliformis[nn]
Clitocybe lactariiformis[1]
Clitocybe virens[n]
Coprinus atramentarius[1]
Coprinus micaceus[n]
Coprinus Spraguei[1]
Cortinarius corrugatus[1]
Cortinellus multiformis[1]
Cortinellus rutilans[1]
Crinipellis zonata[1]
Entoloma sericiceps[1]
Entoloma strictius[1]
Galerula crispa[1]
Galerula hemisphaerica[2]
Geopetalum candidissimum[1]
Gymnopus dryophilus[2]
Gymnopus lachnophyllus[3]
Gymnopus platyphyllus[n]
Gymnopus radicatus[n]
Gymnopus velutipes[1]
Hypholoma appendiculatum[1]
Hypholoma Candolleanum[2]
Hypholoma rugocephalum[1]
Inocybe spp.
Laccaria laccata[1]
Laccaria striatula[2]
Lactaria glyciosma[1]
Lactaria hygrophoroides[nn]
Lactaria piperata[1]
Lactaria rimosella[1]
Lactaria scrobiculata
Lactaria subdulcis[n]
Lactaria varia[1]
Lentinus strigosus[1]
Lepiota sp.[1]
Leptoniella sp.[1]
Marasmius archyropus[1]
Marasmius caryophylleus[1]
Marasmius confluens[n]
Marasmius elongatipes[1]
Marasmius insititius[1]
Marasmius perforans[2]
Marasmius praeacutus[1]
Marasmius resinosus[1]
Marasmius Rotula[1]
Marasmius siccus[n]
Marasmius subnudus[1]
Melanoleuca sp.[1]
Monadelphus illudens[1]
Omphalopsis campanella[n]
Omphalopsis Fibula[nn]
Panaeolus retirugis[1]
Panellus stypticus[nn]
Paxillus involutus[1]
Pholiota Johnsoniana[2]
Pholiota mutabilis[1]
Pholiota praecox[1]
Pleuropus unitinctus[2]
Pluteus cervinus[1]
Pluteus granularis[1]
Pluteus longistriatus[1]
Psathyrella disseminata[1]
Russula flava[1]
Russula foetens[n]
Russula virescens[3]
Schizophyllus alneus[nnn]
Stropharia semiglobata[2]
Vaginata agglutinata[2]
Vaginata plumbea[nn]
Venenarius cothurnatus[1]
Venenarius Frostianus[n]
Venenarius muscarius[1]
Venenarius phalloides[n]
Venenarius rubens[nn]

D. GASTEROMYCETES

Crucibulum vulgare[n]
Cyathus striatus[1]
Dictyophora duplicata[1]
Lycoperdon gemmatum[2]
Scleroderma aurantium[n]

SUMMARY

Ascomycetes	18
Uredinales	15
Hymenomycetes:	
Lower groups	19
Polyporaceae	33
Boletaceae	6
Agaricaceae	86
Gasteromycetes	5
Total	182

A METHOD OF TEACHING ECONOMIC BOTANY

BY EDWARD S. BURGESS

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It may be of interest to put on record a brief synopsis of the method of work in economic botany which I have worked out for Hunter College in New York City—aided by assistant teachers. The course is known as Biology 12, extends through one semester, and occupies 3 hours a week (or 5 when practicable). Students taking this course are young ladies, most of whom expect to teach in the public schools of this city. The conditions under which we work include the following: from 130 to 200 students to be provided for, to be met in divisions or laboratory-sections planned for 20 each, which are supplemented by lectures before a combination of sections, with some use of lantern, and with exhibition of specimens additional to those of laboratory or class use.

The students to be considered are city residents; and as usual with city residents, they have little opportunity for knowledge of the country or of the details of our flora. The other subjects of their college course call for about four fifths of their time or more, and prevent the use of sufficient time in excursion-work to give much of the desired knowledge of natural habitat. Excursions and field-work are taken, but necessarily the principal work is in the class-room.

The relation of this course to others in the college is that it forms the second among the five half-year courses in botany required from all students who select the natural science department. The succession of these required courses is: first, systematic botany (our Biology 11), February to June, with study of morphology and classification of Gymnosperms, Monocotyledons, and spring-flowering Polypetalae; second, economic botany (Biology 12), uses of plants combined with study of Gamopetalae, and with fall-flowering Polypetalae and Apetalae; third, plant physiology

(Biology 13); fourth, Lower Cryptogams; Algae and Fungi chiefly (Biology 15); fifth, Higher Cryptogams, with comparison and review of Spermatophytes (Biology 16).

In planning this sequence, Biology 11–16, it has been my effort to promote both the knowledge and the love of plants, and to arrange each course so that it shall provide individual work from fresh specimens. I also deem it axiomatic that the student's earlier botanical studies should proceed from the known to the unknown; and, therefore, that flowering plants should be quite well understood before beginning detailed work with cryptogams.

In planning this particular portion, Biology 12, our introduction to economic botany, there are also the following special objects:

First, that the student obtain systematized knowledge of the relation of the plant-world to man's use—the special province of economic botany.

Second, that this knowledge be accompanied by distinct conceptions of the plants which furnish economic material; of their names, appearance, habitat, and structure; also of their relationships. Therefore we study them in a sequence of families.

Third, that, so far as possible, our local plants be used as basis for study. Therefore our sequence of families is such as will yield fresh material during the weeks of this course, beginning in September, and avoiding the use for class purposes of any but abundant plants (for our rare plants, and any others which are liable to extermination, should never be gathered for class study.)

Fourth, that foreign plants also should be shown or illustrated, as supplementary matter.

To secure these objects I have arranged a sequence of topics which presents in succession the economic relations of families of plants available in autumn in the vicinity of New York City. It might also be used in its entirety or with appropriate modifications, in many other cities.

I have considered the course as forming properly the second half of a first year in botany; in which year the first half, which with us begins with February, is an introduction to systematic botany (our Biology 11), consisting of studies from seeds and plants, in laboratory and in the field, proceeding from germination-work and the Gymnosperms, through the Monocotyledons and many of the Polypetalae.

Therefore I have deemed it essential to this following course in economic botany that it be based on native fall flowers; that it must cover gamopetalous families with some additions of fall-blooming polypetalous and apetalous families; must include morphological characters but devote emphasis to utilities; must not be confined to succession of families by affinity, but must be influenced in its succession by blossoming-time and availability of material.

With these provisions as requisites, the following is an available approximate order of material used for class work, as now tested for four or five years.

Utilizing the opportunities given by the fall-flowering Gamopetalae, classes take up families somewhat in the following succession:

1. Labiate families; as Scrophulariaceae, Labiatae, Bignoniaceae; with references also to Acanthaceae, etc.
2. Kindred non-labiate families; as Boraginaceae, Polemoniaceae, Convolvulaceae, etc.
3. Orders showing tendency to coalescence in stamens; Cucurbitaceae, Campanulaceae, Lobeliaceae.
4. Coalescence in heads (or cymes); from Hamamelidaceae, Caprifoliaceae, Rubiaceae, to Platanaceae, Valerianaceae, and Dipsacaceae.
5. Coalescence in both stamens and heads; Compositae, Cichoriaceae.
6. Apetalous weedy families; as Ambrosiaceae, Chenopodiaceae, Amarantaceae, Polygonaceae, Plantaginaceae, Phytolaccaceae; with a glance at Euphorbiaceae.
7. Gamopetalous rotate-flowered families; Solanaceae, Apocynaceae, Asclepiadaceae; noting also Gentianaceae and Oleaceae.
8. Polypetalous families; flowers available in fall; as Cruciferae, Leguminosae, Cactaceae; and, fibre available, Malvaceae, Linaceae, Tiliaceae.
9. Apetalous tree-bearing families; Urticaceae, Juglandaceae, Cupuliferae, Betulaceae.

From point of view of their economic relationships, these families have meanwhile yielded subjects of study, approximately in this order:

A. Medicinal plants, sedatives, stimulants, condiments, healing-agents (many of *Scrophularia* and Labiate families).

B. Inert related plants, and associated plants chiefly useful as garden flowers, from the previous, and *Bignonia*, *Verbena*, *Phlox* families.

C. Foods derived from fleshy roots (Sweet Potato) or fleshy fruits (Cucurbits) with glance at the reductions in related parasites (Broom-rape, Dodder) and in submerged plants (*Utricularia*).

D. Beverages and drinks; from Rubiaceae; comparison of tea, chocolate, etc.; consideration of caffeine, quinine.

E. Bitters, herb-teas, folk-medicine; Compositae (with comparison of Gentianaceae).

F. Salad-plants; Cichoriaceae, and comparisons.

G. Weedy plants, their values, their control; reasons for their prevalence; Compositae and Apetalae.

H. Alkaloids and other drugs and important vegetable poisons; Euphorbiaceae, Solanaceae, Apocynaceae, Asclepiadaceae.

I. Oils and perfumes; Oleaceae, Linaceae, etc.

J. Dyes; Leguminosae, and families following.

K. Fodder; Leguminosae.

L. Food from seeds; Leguminosae, Buckwheat, Sunflower, Southwestern Amarantaceae, etc.

M. Food from roots, leaves, etc.; Cruciferae.

N. Mucilage and emollients; Malvaceae, Linaceae, Tiliaceae, Ulmaceae.

O. Fibre, paper, etc.; the preceding families, Moraceae, Urticaceae, etc. Comparison of tissues, with microscope.

P. Rubber, latex; *Ficus*, etc.

Q. Tannin and cork; Cupuliferae.

R. Nuts; Juglandaceae, Cupuliferae.

S. Forests, their value, relation to rainfall, and distribution.

T. Forestry methods, their history in Europe, India, United States, etc.; the present United States Government Forest Reserves.

I add to the above one further explanation; that cereals, most fleshy fruits, and berries are not omitted by accident, but are studied in Biology 11, with the Monocotyledons and Spring Polypetalae.

PHILIPPINE MICROMYCETOUS FUNGI

By Paul Weidemeyer Graff

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Interest in the field of taxonomic mycology with reference to tropical localities seems at present to be on the increase. A number of recent papers have dealt with the situation in the West Indies in a limited way. The situation in our Pacific possessions has received, as yet, so little attention that any contribution, however limited in extent, must be of some interest. It is with this hope that the following enumeration of species collected in the Philippine Islands is offered.

The specimens included in the following list were gathered for the most part in the provinces of Rizal, Laguna, Bataan, and the vicinity of Manila, on the island of Luzon, by E. D. Merrill and the writer. A few incidental collections made by others in various localities are also included. Where several collections of a species have been made in one locality or vicinity, reference has been made to only one, making the citations of distributional value rather than quantitative. All specimens cited are in the herbarium of the Bureau of Science, Manila.

PHYCOMYCETES

Synchytrium de Bary

Synchytrium Puerariae (P. Henn.) Miyabe, Bot. Mag. Tokyo **19**: 199. 1905.

Aecidium Puerariae P. Henn. Bot. Jahrb. **15**: 6. 1892.

Uromyces Puerariae Diet. Bot. Jahrb. **27**: 282. 1900.

Luzon, vicinity of Manila, *Merrill 7424*, November 27, 1910, on leaves of *Pueraria Thunbergii*. Island of Romblon, *Hallier 397*, January, 1904, parasitic on leaves and stems of *Pueraria* sp.

This species was originally described as an *Aecidium* from material collected on *Pueraria sericantha*, from New Guinea, and on *Pueraria Thunbergii*, from Japan, by Hennings. Later it was recognized as a *Synchytrium* by Miyabe. It is probable that Hennings had old and over-mature material as, in this condition, the fungus pustules might easily be mistaken for the aecidia of a rust when given a hasty or superficial examination.

METARRHIZIUM Giard

METARRHIZIUM ANISOPLIAE (Metsch.) Sor. Zeits. Land. Ges. Neu.-Russ. 268. 1879.

Entomophthora Anisopliae Metsch. Zeits. Land. Ges. Neu.-Russ. 21. 1879.

Oospora Destructor Delacr. Bull. Soc. Myc. France **9**: 261. *pl. 14. f. 2.* 1893.

Isaria Anisopliae Pettit, Bull. Cornell Univ. Exp. Sta. 97: 356. *pl. 6.* 1895.

Penicillium Anisopliae Vuill. Bull. Soc. Myc. France **20**: 221. 1904.

Septocylindrium suspectum Mass. Kew Bull. Miscel. Inf. **1**: 4. 1910.

Luzon, vicinity of Manila, *Mackey s. n.*, March, 1914. Parasitic on the rhinoceros beetle.

This fungus, commonly known as "Green Muscardine," has been reported on a number of insect hosts and from a number of localities. It was first found in the Philippines on the cocoanut borer, the larva of the rhinoceros beetle, and appears to be fairly common about the vicinity of Manila. It is also fairly established in the cocoanut district of Laguna Province.

Reported from tropical America, the Hawaiian Islands, Samoa, and Europe.

ACHLYA Nees

ACHLYA APICULATA de Bary, Bot. Zeit. **46**: 635. 1888.

Luzon, vicinity of Manila, *M. A. Barber*, August, 1912, parasitic on fish eggs.

The fungus was producing only zoospores when collected. As the writer desired to use the material for class-room work, pure cultures were made in distilled water on bits of sterile meat and also on tubed agar slants. A number of these cultures were kept growing for some time before they were desired for use, in the hope of inducing the formation of oospores and antheridia. The results were entirely negative until some of the common species of water bacteria were introduced into one of the cultures which had been growing well but producing only a profusion of zoosporangia. After the bacteria had been growing in the culture but a few days the material was examined and a plentiful supply of oogonia and antheridia was found to have been formed. Bacteria were then introduced into other pure cultures with a like result. Pure cultures for zoosporic material and cultures contaminated with bacteria for the sex-organs were then grown on small bits of meat and fly larvae which had been sterilized and hardened in alcohol with the result that extremely satisfactory material was had for laboratory demonstration.

This species was originally described from material collected in Germany.

ASCOMYCETES

ASCOPHANUS Boudier

Ascophanus verrucosporus sp. nov.

Ascomatibus gregariis vel sparsis, immarginatis, convexis, lenticularibus, glabris, sessilibus, badiis, minutis, 0.6–1 mm. diam.; basi filamentis intricatis; ascis maximis, clavatis, apice rotundatis vel truncatis, operculatis, octosporis, 215–245 μ × 30 μ; sporidiis monostichis, ellipsoidiis, minute verrucosis, 22.8 μ × 15 μ, hyalinis; paraphysibus filiformibus, simplicibus, raro bifidis, septatis, miniatis, 258 μ × 3.8 μ.

Perithecia clustered to scattered and sparse, at first closed and lenticular in shape, then expanded, immarginate, convex, fleshy, smooth, sessile, brown, small, 0.6–1 mm. diam. Base on closely interwoven hyphal filaments. Hymenium convex. Asci large, clavate, with rounded to truncate ends which protrude beyond the surface of the hymenium, 8-spored, 215–245 μ × 30 μ, discharging their spores through an operculum. Spores monostichous, ellipsoidal, minutely verrucose, 22.8 μ × 15 μ, hyaline. Paraphyses filiform, usually simple but occasionally bifid, septate, reddish-brown, 258 μ × 3.8 μ.

Luzon, Province of Rizal, Fort McKinley, *Mary S. Clemens s. n.*, February 15, 1912, growing on earth in a moist shaded location.

TRIBLIDIELLA Saccardo

TRYBLIDIELLA RUFULA (Spreng.) Sacc. Syll. Fung. **2**: 757. 1883.
Hysterium rufula Spreng. Sv. Vet.-Acad. Handl. **1820**: 30. 1820.

Tryblidium guaraniticum Sacc. Syll. Fung. **9**: 1103. 1891.

Tryblidiella Balansae Sacc. Syll. Fung. **9**: 1110. 1891.

Rhytidhysterium javanicum Penz. & Sacc. Malpighia **11**: 528. 1897.

Rhytidhysterium guaraniticum Sacc. & Syd. in Sacc. Syll. Fung. **16**: 666. 1902.

Luzon, Province of Bataan, *Bur. Sci. 19092 P. W. Graff*, November 3–19, 1912, on dead twigs in the forest.

Reported previously as being collected in Amboina, New Zealand, Brazil, Guiana, and Cuba, on a variety of hosts.

GENEA Vittadini

GENEA THWAITESII (Berk. & Br.) Petch, Ann. Myc. **5**: 475. 1907.

Hydnocystis Thwaitesii Berk. & Br. Jour. Linn. Soc. Bot. **14**: 110. 1875.

Luzon, Province of Laguna, Mount Maquiling, *Bur. Sci. 16040 Brown*, February 27, 1912, on dead fallen twigs.

This is an interesting fungus which is located systematically between the *Discomycetes* and *Tuberaceae*. When mature, the round or irregular waxy ball opens very much like a *Peziza* with an inrolled margin. The spores, however, are not exposed by this but are still covered by an inner layer of tissue. As a result, the mature specimen has the appearance of a cup fungus with an outer and inner layer of sterile tissue between which is located the unexposed hymenial layer. This species is yellow in color and often opens at the side or irregularly instead of at the top.

Previously collected in Ceylon.

MELIOLA Fries

MELIOLA AMPHITRICHA Fr. Elench. Fung. **2**: 109. 1828.

Sphaeria amphitricha Fr. Syst. Myc. **2**: 513. 1823.

Amphitrichum Hibisci Spreng. Sv. Vet.-Acad. Handl. **1820**: 52. 1820.

Amphitrichum Sacchari Spreng. Sv. Vet.-Acad. Handl. **1820**: 52. 1820.

Luzon, vicinity of Manila, *Bur. Sci. 11002 P. W. Graff*, December 28, 1911, on *Tamarindus indica*.

This fungus has been previously collected in the Philippines on *Pithecolobium apoënse, Sapindus Saponaria* and *Viburnum odoratissimum* but not on the tamarind. It has also been reported from North and South America and Australia.

MELIOLA DESMODII Karst. & Roum. Rev. Myc. **12**: 77. 1890.

Luzon, Province of Bataan, Mount Mariveles, *Bur. Sci. 19025 P. W. Graff*, on leaves of *Desmodium virgatum; Bur. Sci. 19058 P. W. Graff*, on *Desmodium gangeticum*, November, 1912.

Reported also from Tonkin, Indo-China, on living leaves of *Desmodium* sp.

MELIOLA QUADRISPINA Rac. Parasit. Alg. Pilz. Javas **3**: 33. 1900.

Luzon, Province of Laguna, Mount Maquiling, *Merrill 8655*, March, 1913, on leaves of *Hewittia sublobata*.

Originally described from material collected at Buitenzorg, Java, on *Ipomoea* sp.

MELIOLA ARUNDINIS Pat. Jour. de Bot. **11**: 348. 1897.

Panay, Province of Iloilo, *Bur. Sci. 18024 C. B. Robinson*, December 27–31, 1912, on leaves of *Saccharum* sp.

Previously collected at Tonkin, Indo-China, on living leaves of *Arundo Donax*.

MELIOLA SUBSTENOSPORA v. Höhn. Sitzb. Akad. Wiss. Wien 118: 317. 1909.

Luzon, Province of Laguna, Mount Maquiling, *Merrill 8653*, March, 1913, on leaves of *Oplismenus compositus*.

Collected previously at Buitenzorg, Java, on *Phragmites* sp.

MELIOLA MANGIFERAE Earle, Bull. N. Y. Bot. Gard. **3**: 307. 1905.

Luzon, Province of Rizal, Bosoboso, *Bur. Sci. S112 M. Ramos*, October, 1912, on the leaves of *Mangifera indica*.

A species quite common on mangoes in the Philippines. Apparently the fungus is not parasitic but, as in the case of the other members of the genus, appears in connection with aphid attacks, finding nourishment in the honey-dew excreted by them. Any injury to the host is probably due to a smothering effect caused by the heavy incrustation sometimes developed by the fungus. For the most part this fungus is found on the under surface of the leaf.

Described from material collected on the same host in Porto Rico.

Meliola Litseae sp. nov.

Maculis mycelii hypophyllis, rotundato-angustatis, nigrescentibus, gregariis vel sparsis, subcrustaceis, superficialibus, 3–8 mm. diam., margine hyphis radiantibus; hyphis ramosis usque ad 5.7 μ crassis, atro-fuscis, septatis; hyphopodiis capitatis, 15 μ longis, capitulo subgloboso, 7.6 μ latis, oppositis vel alternantibus; peritheciis gregariis vel sparsis, rotundatis, 190–230 μ diam.; setulis rigidis, atris, rectis, abrupte basi curvatis, apice acutis, fuscis, 182–437 μ×7.6 μ; ascis cylindraceis, bisporis, 26 μ×68 μ; sporidiis ellipsoideis, utrinque rotundatis, 4-septatis, constrictis, 13 μ×42 μ, atro-fuscis.

Mycelial spots on the under surface of the leaf, of rather limited area, round, black, sparse to gregarious, becoming confluent, subcrustaceous, superficial, 3–8 mm. in diameter. Marginal hyphae radiating. Hyphal branches uniformly of about the same diameter, 5.7 μ, dark brown, septate. Hyphopodia capitate, about 15 μ long, extremity subglobose, 7.6 μ broad, arranged opposite or alternate on the hyphae. Perithecia gregarious to sparse, round, 190–230 μ in diameter. Setae rigid, dark-colored, upright, with an abruptly curved base, apex acute, brown, 182–437 μ×7.6 μ. Asci cylindrical, two-spored, 26 μ×68 μ. Spores rounded to ellipsoid, 4-septate, constricted at the septa, mature spores averaging 13 μ×42 μ, dark brown.

Luzon, Province of Laguna, Mount Maquiling, *P. W. Graff s. n.*, February 28, 1912, on the under side of living leaves of *Litsea* sp.

PHYLLACTINIA Léveillé

PHYLLACTINIA GUTTATA (Fr.) Lév. Ann. Sci. Nat. Bot. III. **15**: 144. *pl. 7. f. 11.* 1851.

Erysiphe guttata Fr. Syst. Myc. **3**: 245. 1829.

Sclerotium Erysiphe β corylea Pers. Syn. Fung. 124. 1801.

Sclerotium suffultum Rebent. Prod. Flor. Neom. 360. 1804.

Erysiphe Coryli Hedw. f. in DC. Fl. Fr. **2**: 272. 1805.

Erysiphe Alni DC. Syn. Pl. Fl. Gall. 57. 1806.

Erysiphe suffulta Nees, Syst. Pilz. Schw. 148. *pl. 14. f. 134.* 1817.

Phyllactinia Candollei Lév. Ann. Sci. Nat. Bot. III. **15**: 150. *pl. 7. f. 12.* 1851.

Phyllactinia suffulta Sacc. Michelia **2**: 50. 1880.

Phyllactinia antarctica Speg. Boletin Acad. Nac. Cien. Cordoba **11**: 34. 1887.

Luzon, Manila, *Bur. Sci. 9659 C. B. Robinson*, January 28, 1910; *Bur. Sci. 16793*, *S35 P. W. Graff*, September–October, 1912; Province of Bataan, Lamao, *Bur. Sci. 19123 P. W. Graff*, November 6, 1912, on leaves of *Morus alba*.

Though observed in luxurious growth at the end of the rainy season and for some time after, in no case was the perfect form of the fungus found. A yellow spotting of the leaves was caused which advanced as the fungus developed, keeping somewhat ahead of the growth until the entire leaf might be involved. Leaf fall frequently followed.

A fungus of practically universal distribution and found on a great many hosts.

PARODIELLA Spegazzini

PARODIELLA GRAMMODES (Kunze) Cooke, Austr. Fungi 301. 1892.

Sphaeria grammodes Kunze, in Weigelt, Pl. Exs. Surin. —. 1828.

Dothidea grammodes Berk. Jour. Linn. Soc. Bot. **10**: 390. 1869.

Dothidea perisporioides Berk. & Curt. Grevillea **4**: 103. 1876.

Parodiella perisporioides Speg. Ann. Soc. Cien. Argent. **9**: 178. 1880.

Dothidella grammodes Sacc. Syll. Fung. **2**: 634. 1893.

Luzon, Province of Rizal, Antipolo, *Bur. Sci. 21878 M. Ramos*, August 19, 1913, on the under side of leaves of *Desmodium Scorpiurus;* Manila, *Bur. Sci. S148 E. D. Merrill*, January 11, 1913, on leaves of *Desmodium triflorum*.

This fungus has previously been reported from the Philippines on *Crotolaria stenophylla* and *Desmodium capitatum*. It has also been reported from the Islands under the name "*Parodiella pumila* (Cooke) Sacc." on *Desmodium triflorum* and *Smithia ciliata*, which proves to be an error both in determination and typography. *Parodiella puncta* (Cooke) Sacc. is evidently the species intended.

Previously reported from North and South America, Ceylon, India, Australia, and Natal.

ASTERINA Léveillé

ASTERINA PEMPHIDIOIDES Cooke, Grevillea **5**: 16. 1876.

Luzon, Province of Bataan, Mount Mariveles, *Bur. Sci. 19075 P. W. Graff*, November, 1912, on leaves of *Eugenia* sp.

This species seems to be related to *Asterina pelliculosa* Berk. & Br., but has much longer sporidia.

Collected previously in India.

ASTERINA ELMERI Syd. Philip. Jour. Sci. Bot. **9**: 181. 1914.

Luzon, Province of Bataan, Mount Mariveles, *Bur. Sci. 19060 P. W. Graff*, November, 1912, on leaves of *Champeria manillana.*

Found as yet only in the Philippines.

ASTERINA LAWSONIAE P. Henn. in Warb. Monsunia **1**: 159. 1900.

Luzon, vicinity of Manila, *Bur. Sci. S42 P. W. Graff*, on *Lawsonia inermis.*

This collection is interesting in that it is the first of the species reported from the Philippines since the collection of the type material by Warburg in 1888. In the meantime, the species has been collected in India.

PHYLLACHORA Nitschke

PHYLLACHORA CIRCINATA Syd. Ann. Myc. **8**: 38. 1910.

Leyte, Jaro, *Wenzel 559*, February 8, 1914, on *Ficus chrysolepis* in the forest at 500 m. altitude.

This fungus was described from material collected in the Philippines on an undetermined species of *Ficus* and has also been reported on *Ficus odorata.* This collection adds a new host to the list.

Not reported outside the Philippines.

PHYLLACHORA KAERNBACHII P. Henn. Bot. Jahrb. **18**: 39. 1904.

Phyllachora Merrillii Ricker, Philip. Jour. Sci. **1**: Suppl. 280. 1906.

Phyllachora Fici-fulvae Koord. Bot. Unters. 183. 1907.

Phyllachora Fici-minahassae P. Henn. Philip. Jour. Sci. Bot. **3**: 45. 1908.

Luzon, Province of Benguet, *Merrill 7914*, May, 1911, on *Ficus validicaudata;* Manila and vicinity, *Merrill 7468*, January–February, 1911, on *Ficus ulmifolia;* Province of Laguna, San Pablo, *Merrill 7486*, February, 1911, on leaves of *Ficus odorata;* Mount Maquiling, *Bur. Sci. 15988 P. W. Graff*, February 23–28, 1912, on leaves of *Ficus ulmifolia;* Mindoro, Bulalacao, *Merrill 927*, on *Ficus* sp.; Mount Halcon, *Merrill 3579, 5625*, on leaves of

Ficus heterophylla. Balut Island, *Merrill 5422*, October, 1906, on leaves of *Ficus Minahassae*.

The only distinction between the species *Phyllachora Kaernbachii, P. Fici-fulvae* and *P. Minahassae* appears to be age of infection and hostal in nature. In cases where the leaf infections are few and scattered we have one species but if they have become numerous and coalescent with apparently a more even distribution of the fungus stroma we have, according to report, another. The spore and stroma characters in these three species show no specific distinctions.

Collected in Java, New Guinea, and the Philippine Islands.

CHAETOMIUM Kunze

CHAETOMIUM STERCOREUM Speg. Michelia **1**: 222. 1877.

Luzon, vicinity of Manila, *Bur. Sci. 16071 P. W. Graff*, September, 1912, on horse-dung.

The characters of this collection seem to fit in with Spegazzini's species more closely than any other and any differences are not distinct enough to warrant a separation from it.

This seems to be a fungus of very general distribution.

ASTROCYSTIS Berkeley & Broome

ASTROCYSTIS MIRABILIS Berk. & Br. Jour. Linn. Soc. Bot. **14**: 123. 1875.

Rosellinia Bambusae P. Henn. Hedwigia **47**: 256. 1908.

Luzon, Province of Pampanga, Mount Arayat, *Merrill 5030*, 1906; Province of Bataan, vicinity of Limay, *Bur. Sci. 19007 P. W. Graff*, November, 1912, on bamboo.

Previously collected on the culms of dead *Bambusa* sp., at Peradeniya, Ceylon.

TRYBLIDIELLA Saccardo

TRYBLIDIELLA RUFULA (Spreng.) Sacc. Syll. Fung. **2**: 757. 1883.

Hysterium rufulum Spreng. Sv. Vet.-Acad. Handl. **1820**: 20. 1820; Fr. Syst. Myc. **2**: 584. 1823.

Hysterium confluens Kunze, in Weigelt, Pl. Exs. Surin. —. 1828.

Luzon, Province of Rizal, *Bur. Sci. 21885a M. Ramos*, August, 1913, on *Citrus decumana*, associated with *Amphisphaeria hesperidum* Penz.

A fungus of very general tropical and subtropical distribution.

AMPHISPHAERIA Cesati & De Notaris

AMPHISPHAERIA HESPERIDUM Penz. Michelia **2**: 414. 1882.

Luzon, Province of Rizal, Antipolo, *Bur. Sci. 21885 M. Ramos*, August 16, 1913, on dead twigs of *Citrus decumana*.

The perithecia in the mature specimens measure up to 500 μ in diameter with an ostiole of 200 μ. The asci are somewhat longer and more slender than those described by Penzig, measuring on an average 75 μ long and 11.5 μ at their broadest part. The base of the ascus is rather attenuated than thick. The spores vary from 3.8 to 4.5 μ by 14 to 15 μ, corresponding exactly with those of the original description. They are dark brown in color, biguttulate, mono- or distichous and slightly curved. The paraphyses are slender, hyaline, and simple.

Originally described from material collected in Italy on twigs of *Citrus Aurantium*.

MYCOSPHAERELLA Johanson

MYCOSPHAERELLA FRAGARIAE (Tul.) Lindau, in Engl. & Prantl, Nat. Pflanzenfam **1**^{1}: 425. 1897.

Stigmatea Fragariae Tul. Select. Fung. Carp. **2**: 286. *pl. 31.* 1863.

? *Sphaeria fragariaecola* Wallr. Flor. Crypt. Germ. **2**: 767. 1833.

Sphaerella Fragariae Sacc. Syll. Fung. **1**: 505. 1882.

Sphaeria Fragariae Fuckel, in Frank, Krankh. Pflanz. 607. 1880.

Ramularia Fragariae Peck, N. Y. State Mus. Rep. 34: 29. *pl. 3. f. 12–15.* "1881" [1883].

Ramularia Tulasnei Sacc. Syll. Fung. **4**: 203. 1886.

Luzon, Province of Benguet, Baguio, *Bur. Sci. 20968 Wolseley*, February, 1913, on cultivated strawberry plants.

Of very general occurrence through Europe and America. Probably introduced into the Philippines with plants for cultivation.

MYCOSPHAERELLA MUSAE (Speg.) Syd. Philip. Jour. Sci. Bot. **8**: 482. 1913.

Sphaerella Musae Speg. An. Mus. Buenos Aires III. **12**: 354. 1909.

Luzon, Province of Laguna, Los Baños, *Baker 21*, September 10, 1912, on leaves of *Musa sapientum.*

This fungus causes one of the rather common leaf-spots of the cultivated banana in the vicinity of Manila and the surrounding provinces. No great loss is occasioned by its attack, but in severe cases a proportionate weakening of the host must necessarily result.

Probably introduced into the Philippines. Originally described from South America.

MYCOSPHAERELLA PERICAMPYLI Syd. Philip. Journ. Sci. Bot. **8**: 270. 1913.

Luzon, Province of Bataan, Lamao, *Merrill 8679*, January, 1913, on leaves of *Pericampylus incanus.*

Reported as yet only from the Philippines.

MYCOSPHAERELLA ALOCASIAE Syd. Philip. Jour. Sci. Bot. **8**: 195. 1913.

Luzon, Manila, *P. W. Graff*, on living or dying leaves of *Alocasia indica.*

DIDYMOSPHAERIA Fuckel

DIDYMOSPHAERIA STRIATULA Penz. & Sacc. Malpighia **15**: 227. 1901.

Luzon, Province of Bataan, Mount Mariveles, *Bur. Sci. S156 P. W. Graff*, November, 1912, on dead bamboo.

Previously collected in Java.

ANTHOSTOMELLA Saccardo

ANTHOSTOMELLA MIRABILIS (Berk. & Br.) v. Höhn. Fragm. Myc. **6**: 54. 1909.

Astrocystis mirabilis Berk. & Br. Jour. Linn. Soc. Bot. **14**: 122. 1873.

Rosellinia Bambusae P. Henn. Hedwigia **47**: 256. 1908.

Luzon, Province of Bataan, Lamao, *Bur. Sci. 19007 P. W. Graff*, November 3–19, 1912, on dead *Bambusa* sp.; Mount Mariveles, *Bur. Sci. S125 P. W. Graff*, November 10, 1912, on dead *Schizostachyum* sp.

Collected previously in France and Ceylon.

NUMMULARIA Tulasne

NUMMULARIA ANTHRACODES (Fr.) Cooke, Grevillea **11**: 126. 1882.

Sphaeria anthracodes Fr. Linnaea 5: 544. 1830.

Hypoxylon anthracodes Mont. Ann. Sci. Nat. Bot. II. **13**: 359. 1840.

Luzon, Province of Laguna, Mount Maquiling, *Bur. Sci. 15955 P. W. Graff*, February, 1912, on dead unidentified bark; Province of Bataan, Mount Mariveles, *Bur. Sci. 19026, 19054 P. W. Graff*, November 3–19, 1912, on dead tree bark.

Collected previously in Brazil, Guiana, Argentine, and Borneo.

HYPOXYLON Bulliard

HYPOXYLON MARGINATUM (Schw.) Berk. Jour. Linn. Soc. Bot. **10**: 385. 1869.

Sphaeria marginata Schw. Trans. Am. Phil. Soc. **4**: 190. 1832.

Luzon, Province of Bataan, Mount Mariveles, *Bur. Sci. 19055 P. W. Graff*, November, 1912, on dead twigs.

Previously reported from Venezuela, Cuba, United States, Ceylon, and Borneo.

HYPOXYLON RUBIGINOSUM (Pers.) Fr. Summa Veg. Scand. 384. 1845.

Sphaeria rubiginosa Pers. Syn. Fung. 11. 1801.

Luzon, Province of Bataan, Mount Mariveles, *Bur. Sci. 19063, 19081 P. W. Graff*, November, 1912, on a decaying log in the forest.

Previously collected on a great variety of hosts in Europe, North America, Cuba, Ceylon, Java, and North Africa.

HYPOXYLON EFFUSUM Nits. Pyren. Germ. 48. 1867.

Luzon, Province of Bataan, Limay, *Bur. Sci. 19068 P. W. Graff*, November 3–19, 1912, on decaying tree branches.

Common in central and southern Europe.

FUNGI IMPERFECTI

PHYLLOSTICTA Persoon

Phyllosticta Brideliae sp. nov.

Maculis versiformibus, rubro-fuscis, demum griseo-fuscis vel griseis; peritheciis epiphyllis, sparsis vel laxe congregatis, punctiformibus, semiimmersis, minutis, semiglobosis, 50–57 μ × 64.5 μ; ostiolis rotundatis 3.5 μ; sporulis simplicibus, hyalinis, cylindraceis, 1.2 μ × 9.5 μ.

Fungus attack causing reddish-brown irregular anastomosing spots which are evident on both sides of the leaf. Color of spots more dull on the under surface than the upper due to the texture of the leaf surfaces. As the fungus becomes mature the spots become grayish in color and the perithecia break through the upper surface of the leaf. The perithecia are sparse to somewhat gregarious, small, partly immersed and semiglobose, measuring 50–57 μ × 64.5 μ. The ostiole is round and about 3.5 μ in diameter. The spores are cylindrical, 1.2 μ × 9.5 μ, simple and hyaline.

Luzon, Province of Laguna, Mount Maquiling, *P. W. Graff s. n.*, February 22, 1912, parasitic on leaves of *Bridelia* sp.

PHYLLOSTICTA COCOPHILA Pass. Diag. Fung. Nuov. 3: no. 63. 1888.

Luzon, vicinity of Manila, *Bur. Sci. 20644 P. W. Graff*, January, 1913, on leaves of *Cocos nucifera.*

Previously reported and described from material collected in the Botanical Garden of Parma on leaves of *Cocos flexuosa.*

PHOMA Fries

PHOMA HERBARUM West, Michelia **2**: 92. 1880.

Luzon, vicinity of Manila, *Merrill 8463*, December, 1912, on pods of *Cassia occidentalis.*

Previously reported from the Philippines on branches of *Manihot utilissima.* This fungus, with its numerous varieties, is of very general distribution throughout Europe, Asia, and North America.

MACROPHOMA Berlese & Voglino

MACROPHOMA MUSAE (Cooke) Berl. & Vogl. Atti Soc. Venet. **1886**: 187. 1886.

Sphaeropsis ? Musarum Cooke, Grevillea **8**: 93. 1879.

Phoma Musae Sacc. Syll. Fung. **3**: 163. 1894.

Luzon, vicinity of Manila, *Bur. Sci. S166 P. W. Graff*, March 26, 1913, on dead leaves of *Musa paradisaca.*

Collected previously in India.

CONIOTHYRIUM Corda

CONIOTHYRIUM MELASPORUM (Berk.) Sacc. Syll. Fung. **3**: 319. 1884.

Darluca melaspora Berk. in Cooke, Nuovo Gior. Bot. Ital. **10**: 26. 1878.

Luzon, Subprovince of Bontoc, Bauco, *Vanoverbergh 3710*, August 21, 1913, on dead stalks of *Saccharum spontaneum.*

Previous descriptions of this fungus have been so meager in their characterization that the following is appended: Pustules dark, usually long rather than round, when mature up to 1 mm. in length. Perithecia hemispherical with flattened base and rounded top, 280–330 μ broad and 115–160 μ high, at first covered by the epidermis of the stem, which at maturity breaks along the longest axis of the pustule and lengthwise the stem. Spores oblong to oblong-allantoid, 4–4.5 μ × 11–15 μ, light to moderately brown when examined singly, in mass dark brown.

Reported previously from Australia on *Saccharum officinarum.*

NAEMOSPORA Persoon

NAEMOSPORA FICI (Brond.) Sacc. Syll. Fung. **10**: 507. 1892.

Libertella Fici Brond. Rec. Pl. Crypt. Agen. 31. *pl. 8. f. 3–5.* 1830.

Luzon, vicinity of Manila, *Bur. Sci. 11001 P. W. Graff*, December 27, 1911, on leaves of *Ficus* sp.

Reported on *Ficus Carica* in France.

DIPLODIA Fries

DIPLODIA AGAVES Niessl, Hedwigia **17**: 176. 1878.

Luzon, Province of Bataan, Lamao, *Bur. Sci. 20657 P. W. Graff*, November, 1912, on leaves of *Agave Cantula* (*A. americana*); *M. M. Saleeby s. n.*, September 18, 1913, on the same host.

Originally described from material collected on *Agave Cantula* in the Botanical Garden of Calcutta, India.

BOTRYODIPLODIA Saccardo

BOTRYODIPLODIA ELASTICAE Petch, Ann. Roy. Bot. Gard. Perad. 3: 7. 1912.

Luzon, Province of Batangas, Tanauan, *Merrill 8365*, December 19, 1911, on dead branches of *Citrus nobilis*.

A comparison of this collection with Petch's species, described by him as being found in Ceylon on *Hevea brasiliensis* and *Castilla elastica*, seems to indicate their identity.

ASCHERSONIA Montagne

ASCHERSONIA SCLEROTIOIDES P. Henn. Hedwigia **41**: 146. 1902.

Luzon, Province of Bataan, Lamao, *Bur. Sci. 19139 P. W. Graff*, November, 1912, associated with coccids on dead branches of *Citrus* sp.

Reported previously on *Lecanium* sp., on *Castilla elastica* collected at Buitenzorg, Java.

ACTINOTHYRIUM Kunze

Actinothyrium Hopeae sp. nov.

Peritheciis plus minus dense gregariis, orbiculato-scutiformibus, latissime conicis, 415–460 µ diam., fusco-castaneis, contextu fibroso, compacto, margine breviter radiato-fimbriatis; ostiolo manifesto; sporulis cylindraceis aliquantum curvatis, continuis, 11 µ × 49–53 µ, hyalinis; basidiis brevis, simplicibus, hyalinis.

Perithecia more or less densely gregarious, round-shieldlike, center much higher than the sides, making it conical in form, 415–460 µ in diameter, chestnut-brown. Context compact-fibrous. Margin typically of a short radiating fringe. Ostiole present. Spores cylindrical, slightly curved, continuous, 11 µ × 49–53 µ, hyaline. Basidia forming a short, simple, hyaline base.

Luzon, Province of Tayabas, Mount San Antonio, *For. Bur. 19556 H. M. Curran*, December 14, 1911, on living leaves of *Hopea Pierrei*.

GLOEOSPORIUM Desmazières & Montagne

GLOEOSPORIUM PALMARUM Oudem. Contr. Flor. Myc. Pays-bas **14**: 48. 1890.

Luzon, vicinity of Manila, *Merrill 8587*, February 22, 1913, on leaf sheaths of *Areca Catechu*.

Reported in Holland on *Areca sapida*.

PESTALOZZIA de Notaris

PESTALOZZIA PALMARUM Cooke, Grevillea **4**: 115. 1875.

Luzon, Province of Laguna, Mount Maquiling, *Merrill 8646*, March, 1913, on leaves of *Pinanga* sp.

A very common leaf-spot is also caused by this fungus on *Cocos nucifera*, which in severe cases must impoverish the tree. Very severe attacks of this disease have been observed by the writer in the cocoanut districts of Laguna and Tayabas Provinces and the northern portion of the island of Mindoro.

This fungus is of common distribution in the Asiatic tropics.

OIDIUM Link

OIDIUM OXALIDIS McAlp. Proc. Roy. Soc. Vict. **6**: 219. 1894.

Luzon, Manila, *Merrill 8369*, March 12, 1912, on leaves of *Oxalis repens*.

Previously reported and described from material collected on *Oxalis corniculata* in Victoria, Australia.

ASPERGILLUS Link

ASPERGILLUS PERICONIOIDES Sacc. Ann. Myc. **11**: 320. 1913.

Luzon, Province of Bataan, Lamao, *Bur. Sci. S136 P. W. Graff*, November, 1912, on living leaves of *Carica Papaya*.

This fungus is a parasitic species which has been found to attack the leaves of the papaya and, in some cases, apparently resulting in considerable damage to the host. Some of the plants from which this collection was made were losing their leaves in serious numbers. The infection spots spread till the entire leaf becomes involved and premature leaf fall follows.

Not reported as yet outside the Philippines.

HAPLOGRAPHIUM Berkeley & Broome

HAPLOGRAPHIUM ECHINATUM (Rivolta) Sacc. Syll. Fung. **4**: 307. 1884.

Penicillium echinatum Rivolta, Parass. 451. *f. 150–151.* 1873.

Luzon, Manila, *P. W. Graff s. n.*, March 25, 1912, on moist paper which was folded together.

Reported previously from northern Italy on a collection of wheat culms.

CLADOSPORIUM Link

CLADOSPORIUM SUBFUSOIDEUM McAlp. Fung. Dis. Citrus Austr. 79. *pl. 15. f. 21, 22.* 1899.

Luzon, Province of Bataan, Lamao, *Bur. Sci. 21000 P. J. Wester*, June 16, 1913, on leaves of *Citrus Aurantium.*

This fungus has been reported from a number of orange-growing places in the Philippines and is not, in all probability, confined to this species of *Citrus.* It appears to be the common scab-forming fungus affecting citrus trees in the Philippines but is usually found to have other fungi associated with it.

Previously collected on the lemon in Victoria and New South Wales, Australia.

ALTERNARIA Nees

ALTERNARIA BRASSICAE (Berk.) Sacc. Syll. Fung. **4**: 546. 1886.

Macrosporium Brassicae Berk. in Smith, Engl. Flora **5**: 339. 1836.

Polydesmus exitiosus Kühn, Krankh. Kult. 165. *pl. 6.* 1858.

Luzon, vicinity of Manila, *Merrill 8463*, December, 1912, associated with *Cercospora occidentalis* Cooke, on dead pods of *Cassia occidentalis.*

A fungus, with its varieties, of very broad distribution.

CERCOSPORA Fresenius

CERCOSPORA GLIRICIDIAE Syd. Philip. Jour. Sci. Bot. **8**: 283. 1913.

Luzon, Province of Batangas, Santo Tomas, *Bur. Sci. 19127 P. W. Graff*, November 30, 1912; Province of Laguna, Pagsanjan, *Bur. Sci. S161 P. W. Graff*, February 22, 1913, both collections on leaves of *Gliricidia sepium.*

As yet reported only from the Philippines.

CERCOSPORA LITSEAE-GLUTINOSAE Syd. Philip. Jour. Sci. Bot. **8**: 284. 1913.

Luzon, Province of Bataan, Mount Mariveles, *Bur. Sci. 19042, 19073 P. W. Graff*, November, 1912, on leaves of *Litsea glutinosa.*

Reported only from the Philippines.

CERCOSPORA OCCIDENTALIS Cooke, Hedwigia **17**: 39. 1878.

Luzon, vicinity of Manila, *Merrill 8463*, December, 1912, associated with *Alternaria Brassicae* (Berk.) Sacc., on dead pods of *Cassia occidentalis*.

Originally described from material collected on leaves of the same host in the southern portion of the United States.

CERCOSPORA PERSONATA (Berk. & Curt.) Ellis, Jour. Mycol. **1**: 63. 1885.

Cladosporium personatum Berk. & Curt. Grevillea **3**: 106. 1874.

Luzon, Province of Bataan, Lamao, *Merrill 8684*, January, 1913; Province of Batangas, Tanauan, *Merrill 8364*, December, 1911, on *Arachis hypogaea*.

This fungus has undoubtedly been introduced from the United States in connection with the importation of seed for planting in the Islands.

A fungus of common occurrence in the United States and the West Indies.

CILICIOPODIUM Corda

CILICIOPODIUM GRAYANUM Sacc. & Ell. Michelia **2**: 581. 1878.

Luzon, Province of Laguna, Los Baños, *Baker 35*, September 12, 1912, on an undetermined piece of dead wood.

This species has been previously reported from North America.

WEATHER CONDITIONS AND CROP DISEASES IN TEXAS

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The local environment under which plants grow is of interest to collectors and other students of plant life to a degree varying with the particular end in view, or group under observation. For the collector, local soil characters and gross moisture conditions usually serve sufficiently well to indicate the probable habitat in which specimens may be expected. More detail is desirable in the forms commonly regarded as more sensitive to substratum variations such as mosses and hepatics, but herbarium labels and field notes are usually inadequate even in these groups. That the distribution of so readily disseminated forms as parasitic fungi attacking field crops may also show response to environmental conditions of distinctly local character was shown by field observations here recorded.

Following the Gulf storm of August 16 to 20, 1915, in Texas, the damage to the cotton crop by the anthracnose (*Glomerella Gossypii* Edg.) was found to be directly related to the distributions of rainfall during the time the storm was passing over the affected area of the state. But in this case the relation of environment to disease was on a scale of great proportions and was in accordance with one's expectation, except as to degree of damage, which could not be anticipated. In 1916 there was no such great disturbance over the cotton area of the state and local factors were able to act more nearly as distinct elements of the environment. The season was rather dry than wet, though the drouth was not so severe as during the current season. The general condition of the cotton crop in Hill County in the central portion of the state (Texas) was approximately 80 per cent of normal, the drouth stunting the crop to the amount of 20 per cent, considering the general vigor of plants and yield of crop together. Five inspections of separate fields were made near Hillsboro, at distances varying from one half mile to one and one half miles from the starting point; on the west of town, 8 per cent of the bolls were found to be spotted with anthracnose or bacterial spot (*Bacterium malvacearum* E. Sm.). In fields to the south, east and north of town successively the counts rose steadily until the last field inspected showed 26 per cent of the bolls (in scattered counts of 100 each) to be spotted. The airline distance from the 8 per cent field to the 26 per cent one was perhaps three miles, the general character of the land was level, but somewhat broken by shallow erosion washes and depressions, irregularly distributed. It was found, however, that the local showers, though fewer than usual, commonly were more abundant and heavier in precipitation on the east and northeast of the town than elsewhere. The high percentages were in the area of the more frequent showers, *i. e.*, of greater local humidity. This factor was found active at other points also.

Not only is the areal distribution of local rainfall important, but the periodic recurrence of showers is of consequence also. Near Austin, in a field some five miles east of the city, a field was inspected on September 4, 1916, and gave a count of 10 spotted bolls to the 100. On the 23d the same field showed 28 per cent spotted. During the three weeks intervening, several showers had fallen, but apparently none so heavy as to give a half-inch precipitation and conditions were more or less cloudy. This favorable weather lasted for about one week with September 15 as the mean date for the period. The spots in this case were almost wholly due to anthracnose. The seasonal distribution of rainfall is especially important in the case of cotton anthracnose under Texas conditions, where first-class conditions may exist for several weeks in the picking season, only to become suddenly serious by the disturbance in weather conditions due to some tropical storm of more or less severity, as in August, 1915 (Galveston storm), and August, 1916 (Corpus Christi storm). In the eastern cotton states where the normal humidity is greater the degree of damage by these storms is probably less through change of humidity than by mechanical effect of wind and driven rain within the actual path of the storm. These factors are effective in Texas also, as a matter of course, but then further damage results from the disturbed meteorological conditions resulting in continued showers or unsettled weather for some days or even several weeks after the storm has passed.

The dwarfing or stunting of the plants in the field, combined with the elevation of various parts of the same field as a factor influencing disease development, was indicated in a series of counts near Dallas. In a sandy soil a field of some 15 acres sloped from a small run upward to the boundary road, rising perhaps 20 or 25 feet in 100 yards. On the lower side, where moisture was best, and where damp morning air would tend to linger among the trees, the first count showed 8 per cent spotted bolls, mainly bacterial. At intervals of 2 or 3 rods other counts were made in passing to the higher ground. The plants became smaller as the drier parts of the field were approached, the most stunted plants being probably one third smaller than those along the low side of the field. In these plants the count showed 35 per cent of the bolls affected mainly by the bacterial infection. The greater exposure of the individual plants to wind-borne spores was evidently an important factor in the increased degree of spotting, as the spread of plants was reduced as well as their height, thus permitting free circulation of air and germ-laden dust among the plants.

In a field located in a damp spot near a creek, the plants were large enough to meet between the rows, and more than waist-high. Under usual rainfall such a field would be expected to show considerable anthracnose injury. At this time (same day as dry field count) only 5 per cent spotted bolls were found, nearly evenly distributed between the two spot diseases. This field was about three fourths mile from the preceding one reported.

Finally, the occurrence of weather conditions especially favorable for an epidemic development of an infrequent disease may be responsible for serious injuries to specific crops. In the Rio Grande Valley region of Texas, in Hidalgo County, a considerable area is devoted to cotton grown under irrigation. In June of this year many of the fields suddenly showed a marked yellow color of the leaves. Specimens sent to the Experiment Station were identified as *Aecidium Gossypii* (Science II. **46**: 268. 14 S 1917). The affected fields were visited by the writer in July and the aecidial irruptions found to be generally past activity and commonly invaded by the rust-parasite *Tuberculina* in so far as the leaves still attached to the plants were concerned. These were, however, far fewer in number than those affected earlier, as shown by the dry leaves under the plants in the rows, which were shed by the plants before becoming parasitized.

The disease was noted almost simultaneously by Dr. Morton of Mercedes and County Agent Miller of Edinburg, from both of whom specimens were sent to the Experiment Station. Field inspections and interviews four weeks later showed the epidemic to be past, and no fresh areas developing. It was learned that about two weeks previous to the observed outbreak of the disease about a week of showers and cloudy weather had occurred, this being distinctly unusual in that section. After making allowance for possible inaccuracy of statement, it seems probable that the disease was present in cotton fields on the Mexican side of the Rio Grande, as Dr. Morton learned of "yellow leaves" occurring in that locality. Southwest winds prevail during much of the season in that part of Texas, and invasion of spores from the alternate host (as yet unknown) or possibly viable sporidia from germinating teleutospores might be carried over the half mile of river between the Mexican and American fields. According to Dr. Morton, the trouble spread northeasterly from Rio Grande City or Sam Fordyce to Edinburg and Donna, making a total travel of 25 or 30 miles in a couple of weeks or less, according to his observations and conversations with farmers.

An interesting ecological detail was learned during a personal inspection of the fields, namely, that those fields suffered most which were nearly ready to show first blooms. Fields either older or younger were less seriously injured. This was shown in the fields showing effects of serious damage by the presence of bolls with the involucral bract and calyx carrying aecidial sori; fallen leaves with the rust areas in abundance were numerous under such plants.

There may be some close relation between the date of application of irrigation water to the field and the appearance therein of the rust. This point did not come to mind in time to receive attention while in the field, but may have an important bearing through the use of the Rio Grande water as a vehicle of transport of debris of vegetation in which the telial phase of the rust might have been distributed. This possibility would help to explain the uniformity in degrees of infection existing over entire field, as though irrigation water had been in some way related to the epidemic, as well as the age of the crop plants.

About a week after my visit, Dr. E. W. Olive examined the affected area and confirmed the above details from his observations and interviews. In addition he learned from one or two of the more observing farmers that the aecidial sori had been seen scatteringly as early as late April of this year, and apparently the same trouble noticed, though doing no essential damage in other years. This would indicate that the aecidial stage (and by inference the other stages of the rust) has been present for some time as a parasite too insignificant as to damage to come to notice as a "disease" until the special conditions of weather and crop development made the outburst this season possible, as an epidemic. This would appear to be confirmed by the abundance of infections of the aecidial sori by the secondary parasite *Tuberculina*, which at that season would hardly find other hosts (rust) in abundance (sunflower, cocklebur and Bermuda-grass leaves with rust pustules appeared to be free from the *Tuberculina*).

The sudden cessation of fresh infection with the passing of favorable weather conditions is in keeping with similar sensitiveness among other rust species, and is one of the natural checks to the spread of such parasites.

The above examples indicate the intimate relation that evidently exists between the healthy development of crop plants and the injuries caused by invasion of parasitic fungi producing disease conditions. The influence of climatological changes over considerable areas or during a number of days or weeks has been recognized for a long time, but the direct relation of small variations in limited areas has been less evident. In connection with diseases conveyed from season to season in planting seed (*e. g.*, bean anthracnose, cotton anthracnose), the saving of such seed from areas of lightest local rainfall, and during the most favorable period for seed-ripening becomes a practice of demonstrable value based on "crop hygiene."

EARLY HORTICULTURAL JOURNALISM IN THE UNITED STATES

By James Grimshaw Scott

Germantown, Pennsylvania

"Time consecrates and what is gray with age becomes Religion."

On the authority of our most accurate Germantown historian, Edwin C. Jellett, we have it that the pioneer horticultural journal was the *Florist and Horticultural Journal* founded in Philadelphia in 1852 by R. Robinson Scott.

In presenting to you the facts of the beginning of horticultural journalism in these United States, I have taken the stated "text" from the pages of the Philadelphia *Florist and Horticultural Journal*, the first issue of which came from the press in April, 1852, and the publication of which was suspended in 1855, having run through part of that year.

Explaining the suspension of publication, the editor printed the following: "The only apology we have to make for our suspension, to those of our subscribers who paid us promptly their subscriptions, is, that a greater number have not paid and some, perhaps many, do not intend to pay."

This shows that the *Journal* was an indigenous one—not an exotic, as the circulation editor of a journal of any kind to-day will advise you that this condition of the finances is normal throughout the country. We must not censure the delinquents for the state of affairs entirely, for the publication is often thrust upon them by the importunities of the publishers and the charm of the journal so grips the reader that he is loth to cancel his subscription even when he has no funds with which to pay for it.

This period, say from 1850 to 1860, seems to have been the golden age of horticulture in the United States and the storm area extended from Massachusetts to Maryland, where many earnest workers were engaged in planting the wilderness and encouraging the remainder of the country to cultivate the soil.

To the publishers of this pioneer horticultural magazine it seemed a necessity to have an organ devoted entirely to botany, horticulture and pomology and of this necessity the Philadelphia *Florist and Horticultural Journal* was born. At the time of its first appearance there were journals that "dabbled" in the news of the farm and garden but this was the first strictly horticultural and agricultural journal to be attempted in the New World.

New York too, at this time, had her horticultural dreams and ambitions and one of the first secretaries of a New York Horticultural Society was George William Curtis.

Hon. Marshall P. Wilder of Massachusetts, no doubt a kinsman of our late beloved Prince of Entertainers, "Little Marsh," seems to have held the New England front. The Honorable Nicholas Longworth, of Ohio, was the active spirit in the horticulture of the then far western limit of activity.

On the last page of the last issue of the Philadelphia *Florist and Horticultural Journal,* we find notes of three other contemporary journals, namely, the *Western Agriculturist,* published in Pittsburgh; the *Homestead,* published in Hartford, Conn.; and the *Pennsylvania Farm Journal,* published in Philadelphia by Messrs. Samuel Emlen & Co. and edited by David Wells and A. M. Spangler. Samuel Emlen still survives in our Germantown and he of all others was the most helpful spirit in encouraging these early garden publications. It was he who, with the late John Jay Smith, steadied the hand of the editor and proprietor of the pioneer *Florist and Horticultural Journal,* applauding him when he ran, lifting him when he fell, and enabling him honorably to proceed with the work which made a place for the *Journal* and blazed the way for those that followed. From that early time till now the United States has been benefited by the stimulus of splendid horticultural journals until at the present time we find that flowers and fruits, deified by the refined ancients under the titles of Flora and Pomona, have unseated Jove, who grasped with mailed hand the thunderbolts of Heaven; and to-day, passing the City Hall of Philadelphia, we read the inspiring announcement, "Food will win the war—don't waste it."

Reared then in the atmosphere of the stoke-hole among the tobacco stems and grafting twine in the caboose at the end of the greenhouse, we are pleased to salute the pagan deities Pomona and Flora and brush impatiently aside all other fabulous personifications.

This pioneer horticultural journalist was besides the pioneer fern student of the United States and his memory has been kept green by those beloved publications, the *Fern Bulletin* and its successor, the *American Fern Journal*, in whose pages may be read the enchanting history of *Asplenium ebenoides* R. R. Scott, one of the most noted of the world's ferns.

It gives me great pleasure to revive the memory of the early *Journal* and in the brief time at my disposal, I cannot refer to the splendid magazines that have succeeded it until to-day we are in possession of the crowning effort in that distinguished quarterly, the *Addisonia* of the New York Botanical Garden.

The memory that endures is the consecrated shrine of the historian and the Greek statue of antique time is of greater value than the whole of Manhattan Island!

SISYRINCHIUM BERMUDIANA

By Oliver Atkins Farwell

Parke, Davis and Company, Detroit, Michigan

Many botanists have in the past considered the pale-blue-flowered *Sisyrinchium Bermudiana* L., of the Atlantic coast, and the violet-blue *S. iridioides* Curtis, of Bermuda, to be conspecific and have united them under the Linnaean name. Philip Miller, who cultivated both, side by side, considered them to be amply distinct and described them separately in the Gardeners Dictionary in 1768 but applied the Linnaean name to the Bermuda plant and renamed the Atlantic coast species as *S. angustifolium*. William Curtis, who, like Miller, knew both plants, also considered them to be distinct and in the Botanical Magazine, plate 94, named the Bermuda plant *S. iridioides;* the date of the title page of volume 3 of the Botanical Magazine is 1790 but the printed date on the plate itself is September 1, 1789; the publication of the binomial must, therefore, date from that of the plate, 1789. Modern botanists follow the interpretation of Philip Miller by applying the name *Sisyrinchium Bermudiana* L. to the plant that is endemic in the Bermudas but this is contrary to the laws of priority as expressed in both the Vienna and American codes. Both of these species were described and illustrated by Plukenet in the Almagestum under his genus *Sisyrinchium;* likewise by Dillenius in Hortus Elthamensis under the Tournefortian genus *Bermudiana.* Linnaeus in the Species Plantarum, page 954, 1753, combined both species under the binomial *Sisyrinchium Bermudiana*, thus preserving to science both of the old generic names under each of which the species had previously been known. The specific name *Bermudiana* perpetuates an old generic name and cannot be considered as having been given to the species as a geographical name to indicate the nativity of the species; had that been the idea actuating Linnaeus he in all probability would have given it the name *bermudiense* adopting it from Plukenet *providing he had* *intended the Bermudian plant to be the type of the species.* But Hemsley has already shown (Journal of Botany **22**: 108–110. 1884) that Linnaeus *in all probability had never seen the plant from Bermuda.* As a matter of fact he made the Bermuda plant his var. β and considered it to be of such small categorical importance that he did not give to it even a varietal designation. That he intended the Virginia plant to represent typically his *S. Bermudiana* is clearly proved by the fact that all references to it were enumerated under his specific name and description while those referring to the Bermuda plant were grouped under his unnamed variety β and by the fact which is still more to the point, that the explanatory note with its fuller description was drawn entirely from his "Planta α," *i. e.*, the Virginia plant. A careful study of all the evidence seems to indicate that:

1. Linnaeus probably never saw the plant from Bermuda.

2. The specific name *Bermudiana* perpetuates an old generic name and was not used as a geographical name to indicate the origin of the species; this view *per se* would prevent the adoption of the Bermuda plant as the type of the species.

3. The Linnaean descriptions (diagnosis and footnote) are based upon the plant from Virginia, which must therefore be taken to be the type of the species.

4. The plant from Bermuda should be known under the first name applicable to it, *S. iridioides* Curtis.

THE EFFECT OF ACIDS AND ALKALIS ON THE GROWTH OF THE PROTOPLASM IN POLLEN TUBES

BY FRANCIS E. LLOYD*

McGill University

In 1915 it was shown† that the protoplasm of pollen grains acts in the presence of acids, alkalis, and salts in general accordance with the behavior of the biocolloid gelatin. The evidence then secured appears to indicate that the amount of swelling is greater in acids than in alkalis, and less in salts than in pure water, from which, in the light of MacDougal's experiments, the preponderating protein component of the complex may be inferred.‡ It soon became evident, however, that the amount of swelling for various concentrations of solution of the reagents used was not constant, and it was found necessary to determine this relation for an assumed analog, gelatin, and then to find the material and method by which the comparative behavior of the protoplast in the living condition could be studied. The results of the measurements of the swelling rates of gelatin in a number of acids and alkalis, and these in combination with certain salts have been reported upon in general form.§ These are in brief as follows:

1. The swelling rates differ in both acids and alkalis for different concentrations. The maximum rates are found at certain concentrations above *ca.* $N/640$, which are higher for organic acids than for inorganic acids. At higher concentrations "repression"|| occurs. The higher rates are at first at higher concentrations, but as time elapses the rates at successively lower concentrations

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* The writer acknowledges the assistance of a subvention from the Cooper Fund for Medical Research, McGill University.

† Lloyd, F. E. Carnegie Inst. Wash. Ann. Rep. for 1915.

‡ MacDougal, D. T. Science II. **44**: 502. 6 O 1916.

——— & Spoehr, H. A. Science II. **45**: 484. 18 My 1917.

§ Lloyd, F. E. Trans. Roy. Soc. Canada, 1917 (In press).

|| Procter, H. R., & Wilson, J. A. Jour. Chem. Soc. London **109–110**: 307–319. 1916.

overtake them. At certain concentrations below *ca.* *N*/640, *the rates are lower than those for pure water,* but much more markedly so for acids than for alkalis.

2. The swelling rates and total swelling in acids is greater than in alkalis.

3. The swelling rates and total swelling is greater in some organic acids (citric, malic) than in inorganic acids.

Acetic and tartaric acids appear to be excepted. Malic acid has a far-reaching effect on gelatin in causing it to fragment at *N*/160 and above after one to two hours. This fact, together with the lower swelling rates at the higher concentrations, suggests that at these there is a coagulation effect which sets in to repress swelling.

It thus appears that in trying to establish any analogy between gelatin (or other emulsoid) and protoplasm, *the concentrations of the reagents to which they are subjected must be considered.* For example, during the increase or decrease of acidity which may take place in the living tissues, the swelling effects may be alternately repressed and increased, aside from alterations in the relative composition of the body fluids due to change in salt, protein, or other content, such as MacDougal has indicated.*

The determination of growth rates and accompanying phenomena in pollen tubes confirms the expectation that their protoplasm behaves toward the above reagents in many important respects as does gelatin rather than agar.† The method employed consists in sowing pollen of *Phaseolus odoratus* in hanging drops of the various reagents at different concentrations, associated with cane sugar in constant concentration, it having been found‡ that the rate of growth of pollen tubes is inversely as the concentration of cane sugar, the maximum accomplished growth occurring in *ca.* 20 per cent solution. It has been shown that this is explainable on the assumption that imbibition by the protoplasm rather than osmotic pressure is the dominant growth factor. In weaker solutions of cane sugar the pollen tubes burst, the lower the concen-

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* MacDougal, D. T. Science II. **46**: 269. 14 S 1917.

† The contrary has been found to hold for complex tissues such as cactus stems by MacDougal and Spoehr. Proc. Amer. Phil. Soc. **56**: 289. 1917 (and other already cited papers).

‡ Lloyd, F. E. Carnegie Inst. Wash. Ann. Rep. for 1916.

tration the more quickly, and for this reason little total growth can be attained, although the initial rates are higher than that at higher concentrations. The cultures were run in a double series, and the concentrations of acid and alkali were varied between *N*/25,600 and *N*/100.

During the course of experimentation it was found that positive results in terms of growth could be obtained with alkali when associated with 20 per cent cane sugar, but that acids so associated caused the pollen grains or tubes to burst. This again indicated the greater swelling effect of acid over alkali. It was then found that by increasing the concentration of cane sugar to 40 per cent, the effect of acids was held in check and that growth proceeded, bursting taking place only at certain concentrations of acid, but in the lower of these only after a certain amount of growth had been attained. With this difference understood, it was shown that the behavior of the growing protoplasm was otherwise and in general the same toward both acids and alkalis. Summarily stated it is as follows:

At certain concentrations of the reagent, growth proceeds more rapidly than in the control, namely, the pure cane-sugar solution. The maximum growth occurs for acetic acid at *N*/3200, for malic acid at *N*/12,800, and for citric acid at *N*/12,800, or perhaps less. Hydrochloric, formic, and oxalic acids did not afford positive results in terms of growth, and indeed the evidence for citric acid was not unequivocal. This was not because they did not produce increased imbibition in the protoplasm, but probably because of pathological results which militated against the attainment of growth. It is important to note that for those acids which gave the data sought, there was less growth for concentrations above and below the ones just indicated, and in this we may see a correspondence with gelatin in its maximum swelling response to certain concentrations already mentioned. The correspondence is heightened in the growth rates which in low concentrations of the reagents are lower than in the control. It was previously shown that essentially the same behavior occurs in alkali, sodium hydrate having been used.

That a higher concentration of cane sugar must be used with acids may be due to the already acid condition of the protoplast.

Growth took place in alkali also in a greater range of concentrations, namely, from *N*/400 to *N*/25,600, and it was determined that the Na-ions penetrated the protoplast. In *N*/400 the growth was less than in the control, this, it is possible, being related to an increase in salts formed. At all other concentrations the amount of growth was greater than in the control, increasing from the lowest concentration used to *N*/3200 and falling for those still higher.

The failure to obtain positive results with certain acids in terms of growth, as above stated, need not, indeed should not, be interpreted except as indicating that other effects antagonistic to normal behavior intervene.

We may note especially the bursting of the protoplast beyond the confines of the cell wall. The weakest point in the pollen-tube wall is at the apex, and it is here that bursting takes place if it has not already occurred before growth begins. Bursting is due to the imbibition of the protoplast beyond the strength of the wall to confine it, and not, as might be expected, to any change in the wall itself, such as hydrolysis, since the bursting takes place more rapidly at concentrations of the reagent which would cause less hydrolysis.

In acids the bursting takes place within a certain range of concentrations, namely, those above that at which maximum growth takes place and below those at which syneresis of the protoplasm is caused. Syneresis is quite evident in all the acids studied at concentrations at or above *N*/3200, and it is of more than passing importance that syneresis occurs in formic, oxalic, and hydrochloric acids at lower concentrations (*N*/3200 to *N*/1600) than in citric, malic, and acetic acids, and was not observed at all in alkali. It is evident in the course of a short time in the highest concentrations (*N*/800 to *N*/400) but ensues more slowly in the lower effective concentrations. It should be stated that in all these the protoplast swells fully when first subjected to them, completely distending the pollen-grain walls. It then slowly shrinks.

At the close of shrinkage it can be shown that the protoplasm is coagulated, for on pressure it breaks out as a cheesy mass. In this connection it is important to note that at the higher concentrations at which bursting occurs, the protoplasm oozes out of the broken pollen tube in strings, in such a manner as to show that it has a much higher viscosity than has the protoplasm exposed to the same reagent at lower concentrations but which nevertheless cause bursting.

It will thus be seen that the maximum swelling of the protoplasm is at the concentration of the reagent which causes the most rapid bursting, and this is higher than the concentration which causes swelling which can be utilized in growth. The former is chiefly a physical result, the latter physiological. A glance more particularly at the behavior of pollen protoplasts toward malic acid may be taken, this serving as a typical example.

At concentration	There occurs:
N/400	Coagulation and complete syneresis in the course of an hour of all the pollen grains (100 per cent.).
N/800	The same but more slowly and less completely (95 per cent.).
N/1600	50 per cent. of the pollen grain shrinks in the course of 3 hours, the remainder having burst; the protoplasm highly viscous, bursting in strings after some growth (0.3 unit).
N/3200	Bursting of 90 per cent. after 1–1.5 units growth attained; viscosity of protoplasm lower than above but still showing coagulation ("clots").
N/6400	3.5 units growth in 5 hours. Some bursting but no coagulation. 22 hours later: alive, no further growth.
N/12,800	8 units growth in 5 hours, no bursting; 22 hours: 16 units growth, alive.
N/25,600	4 units growth in 5 hours; 22 hours: 5 units growth, alive.
Control:	4.5 units growth in 5 hours; 22 hours: 5 units growth, alive.

In formic acid, bursting unaccompanied by coagulation occurred in *N*/25,600 (with 20 per cent cane sugar) after one unit of growth was attained. Partial coagulation occurred in *N*/6400, more in *N*/3200 and complete in *N*/1600.

The above results indicate that the protoplasm of pollen grains is affected by acids and alkalis in the same fashion as gelatin, and that the increased swelling caused by such reagents can actually be used in growth. The extreme sensitiveness of this protoplasm to low concentrations of acids and alkalis, as evidenced in coagulation and syneresis in the higher, and in the swelling and growth in the lower, is to be noted. It has become patent that the mechanism of growth in more complex plants includes emulsoids which exhibit swellings at much higher concentrations of acids and alkalis* and a final analysis of their relations to growth must, as it will, include the behaviors of these emulsoids. Similarly in the animal body, so far as studied in these relations, it is impossible to analyze the phenomena, and to separate that which occurs in substances extraneous to the protoplasm (*e. g.*, sarcolemma), and that which occurs in the protoplasm itself.

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* Long, E. R. Bot. Gaz. **59**: 491. 1915; MacDougal & Spoehr, as above cited; Fischer, M. Oedema, 1910.

THE ORIGIN OF THE HAWAIIAN FLORA

BY DOUGLAS HOUGHTON CAMPBELL

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The Hawaiian Islands afford perhaps the most important problem in plant distribution that exists anywhere. The most isolated land area of equal size on the globe, the origin of their extremely peculiar and interesting flora opens a wide field for research and speculation.

There is much difference of opinion as to whether or not the Islands have had at any time connection with any of the great continental areas. Hillebrand,* whose flora of Hawaii is well known, and has been followed in the tables given in this paper, believed that the Islands had always been isolated, having been thrown up from great ocean depths through volcanic action. This view has been recently advocated by Muir† as the result of his studies on the insect fauna of the islands. On the other hand, Wallace,‡ on the basis of the occurrence of certain north temperate genera in the high mountains of Hawaii, believed that there had been a land connection with west North America. Recently, Pilsbry§ has brought forward evidence which he thinks proves conclusively some ancient connection of the Islands with the Malaysian region. The peculiar land-snails, so largely developed in the Islands, are, according to Pilsbry, ancient forms, whose survival outside of the Pacific Islands is known only in the Malaysian region.

The writer, up to the present time, has taken it for granted (largely on Hillebrand's evidence) that the Islands always had been completely isolated; but the evidence offered by Pilsbry for an ancient land connection seems very strong, and, moreover, is

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* Hillebrand, W. Flora of the Hawaiian Islands. 1888.

† Muir, F. Proc. Haw. Ent. Soc. 3: 198–200. 1916.

‡ Wallace, A. R. The geographical distribution of animals, 1: 447. 1876.

§ Pilsbry, H. A. Mid-Pacific land-snail faunas. Proc. Nat. Acad. Sci. 2: 429–433. 1916.

quite in line with certain facts of plant distribution which appear to have been overlooked.

The occurrence in the Islands of many hygrophilous liverworts and the filmy ferns (Hymenophyllaceae) seems to make it practically certain that, as in the case of the snails cited by Pilsbry, the presence of these in the Islands can be explained only by considering them as remnants of the flora of a formerly much more extensive area connecting the Islands with some ancient continent. These plants are peculiarly unfitted for transportation over long distances and it is difficult to see how they could possibly have survived the exposure to heat and dryness to which they must have been subjected, assuming that they have come directly from either the American tropics or the remote tropical regions to the south. These plants inhabit, for the most part, the cool dark rain-forests and are quickly destroyed by exposure to the heat and sunshine of the lower levels.

During the past summer the writer made a brief visit to the Islands, with a special view to examining the hepatic flora; and although the collections made were not as comprehensive as it was hoped to make them, owing to the remoteness of the collecting grounds, the results tend to confirm Pilsbry's view of a connection with the Malaysian and Australasian region.

The most conspicuous of the liverworts in the lower forests are two species of *Dumortiera*, a genus peculiarly adapted to wet dark conditions. According to Stephani's* list of the liverworts of Hawaii, these species are *D. trichocephala* (Hook.) N. ab E., a species widely distributed through the eastern tropics, and *D. hirsuta* (Sw.) R. Bl. & N., an even more widely spread species. It is probable, however, that a critical examination of the Hawaiian plants will show that they are not identical with those species. The so-called *D. trichocephala* is certainly quite different from material of the same species collected in the Malayan region, and the form attributed to *D. hirsuta* resembles very closely the Javanese *D. velutina* Schiffn. Stephani states also that the monotypic genus *Wiesnerella*, which is closely related to *Dumortiera*, occurs in Hawaii, and immature material collected by the writer perhaps belongs here. This species occurs also in Java, the Himalayas, and Japan.

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* Stephani, F. Hepaticae Sandvicenses. Bull. Herb. Boiss. 5: 840–849. 1897.

The writer found repeatedly a species of *Megaceros* closely resembling the species first described by him from Java* but afterwards found abundantly throughout the Malayan region. This genus, like *Dumortiera*, is characteristic of very wet, shady localities, and its thin-walled, green spores are certainly not fitted to being dried up and transported over long distances by the wind. The same may be said of the related genus, *Dendroceros*, which inhabits the dripping rain-forest of the higher altitudes. The latter was found by the writer only at an elevation of about 4000 feet, in regions of almost constant rain.

Other characteristic thallose liverworts of the upper rain-forests were species of *Pallavicinia*, *Symphyogyna*, and *Aneura* (*Riccardia*). One of the last-named genus appears to be very close to *A. maxima* Schiffn. of Java.

It may be safely asserted that there is a marked resemblance between the liverwort floras of Hawaii and the Malaysian region, but further material is necessary before the exact degree of relationship can be established.

The Islands at present consist almost solely of volcanic masses, and it is very evident that the volcanic activity has proceeded from the northwest to the southeast.

The oldest formations in the north island, Kauai, and part of Oahu, show much weathering and disintegration, while in the newest and largest island, Hawaii, volcanic activity is still in progress.

Hillebrand made a careful study of the distribution of the vascular plants of the Islands and found that there is a marked increase in the number of species, especially endemic species, in the older islands, this being specially marked in Kauai, where presumably the evolutionary forces have been at work for the longest time.

The preponderance of the Australasian-Malaysian elements in the Hawaiian flora, indicated by a study of the liverworts, is amply confirmed by a comparison with the vascular plants. This will be sufficiently evident from an examination of the tables appended, based upon Hillebrand's Flora of the Hawaiian Islands.

It is evident at a glance that the Australasian, Polynesian, and

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* Campbell, D. H. Ann. Bot. 21: 469. 1907.

Malaysian genera are much more numerous than the American. There are forty-five genera of Phanerogams belonging to the former regions which are entirely absent from the New World; while only eight genera are exclusively Hawaiian-American. One genus, *Gynandropsis* (Capparidaceae) belongs to South America and South Africa, while three endemic Hawaiian genera of Compositæ—viz., *Argyroxiphium*, *Wilkesia*, and *Raillardia* are closely related to certain Californian types.

The Pteridophytes emphasize even more strongly the intimate relation between the floras of the Australasian and Malaysian regions and Hawaii. No less than thirty-eight species, absent from America, are common to the two areas, while only two species are confined to Hawaii and the American continent.

While it is not unlikely that certain species of Phanerogams common to Hawaii and the southern Polynesian region may have been introduced in recent times, in most cases the Hawaiian species are distinct and peculiar to the Islands. The cocoanut, taro (*Colocasia*), sugar-cane, bread-fruit, and some other cultivated plants were undoubtedly introduced by man, and it is not unlikely that such useful trees as the kukui (*Aleurites moluccana*) and the mountain apple (*Eugenia malaccensis*) were also introduced, although now they form almost the entire forest of the lower elevations.

The American-Hawaiian genera are mostly found in the Andean region and as there is considerable evidence of a former connection of South America with the Australasian region, it is possible that some of these forms may have reached Hawaii from the south and have survived in the two extremes of their range, disappearing in the intermediate regions.

While it is extremely probable that some species reached the Islands since their complete isolation, either by means of ocean currents, wind, or the agency of migratory birds, this, as conditions are at present, could have taken place only under very exceptional circumstances. It is difficult to see how any of these agencies would account for the introduction of many plants of the cool rain-forest, which could hardly survive any such means of transportation.

As to the line of connection between Hawaii and some former continental or sub-continental area, we can only conjecture. An examination of the water areas existing at present (see map 2, Century Atlas) shows that between the Islands and North America there is an enormous and perfectly continuous area of very deep water which extends to the north and to the south of the Islands, but leaves an opening on the west which is continuous with a large area of less depth comprising pretty much the whole of Polynesia. To the southwest are two very large shallow areas including respectively the Marshall and Caroline Islands, presumably the remains of large sunken land masses. A chain of similar but smaller shallows extends to the Malay Archipelago, and it is possible, at least, that this indicates approximately the line of connection between Hawaii and some ancient great southern continent—in short, that Polynesia comprises merely the remnants of a larger continent, or group of continental islands like Australia.

As to the period at which Hawaii became completely isolated, this of course can only be guessed. It could hardly have been earlier than the later Cretaceous or early Tertiary since few of the modern Angiosperms existed prior to the upper Cretaceous, so far as we know.

Hillebrand, reasoning from the absence of Conifers, thinks that the Islands must have been formed "subsequent to the age in which these were universally distributed." It is quite conceivable that Conifers may have existed formerly and become extinct as the result of the extensive volcanic activities subsequent to the isolation of the Islands. As the soils of the Islands at present are practically exclusively volcanic and are said to be strongly acid, this might well account for the absence of many plants which may have been found at an earlier period, but which require different soil conditions from those now existing.

The subsidence of the assumed ancient Pacific continent perhaps coincided with the great uplift during the late Cretaceous when most of the existing mountain systems of western America came into existence.

Australasian-Malaysian genera occurring in Hawaii, but not in America

Pittosporum Banks	Pittosporaceae
Eurya Thunb.	Ternstroemiaceae
Elaeocarpus L.	Tiliaceae
Byronia Endl.	Ilicaceae

Alphitonia Reissek	Rhamnaceae
Strongylodon Vogel	Leguminosae
Mezoneuron Desf.	
Metrosideros Banks	Myrtaceae
Tetraplasandra A. Gray	Araliaceae
Reynoldsia A. Gray	
Gardenia L.	Rubiaceae
Plectronia L.	
Coprosma Forst.	
Scaevola L.	Goodeniaceae
Cyathodes R. Br.	Epacridaceae
Embelia Burm.	Myrsinaceae
Ochrosia Juss.	Apocynaceae
Alyxia R. Br.	
Cyrtandra Forst.	Gesneriaceae
Myoporum Banks & Sol.	Myoporaceae
Plectranthus L' Hérit.	Labiatae
Phyllostegia Bent,	
Achyranthes L.	Amarantaceae
Wikstroemia Endl.	Thymeliaceae
Santalum L.	Santalaceae
Exocarpus Labill.	
Viscum L.	Loranthaceae
Claoxylon A. Juss.	Euphorbiaceae
Aleurites Forst.	
Antidesma L.	
Pseudomorus Bureau	Urticaceae
Pipturus Wedd.	
Cypholophus Wedd.	
Anoectochilus Blume	Orchidaceae
Cordyline Commers.	Liliaceae
Dracaena Vand.	
Astelia Banks & Sol.	
Dianella Lam.	
Joinvillea Gaud.	Flagellariaceae
Pritchardia Seem. & Wendl.	Palmaceae
Pandanus L.	Pandanaceae
Freycinetia Gaud.	
Baumea Gaud.	Cyperaceae
Gahnia Forst.	
Garnotia Brogn.	Graminaceae

HAWAIIAN-AMERICAN GENERA, NOT FOUND IN THE AUSTRALASIAN REGION

Genus	Family
Perrottetia H.B.K.	Celastraceae
Vallesia Ruiz & Pav.	Apocynaceae
Nama L.	Hydrophyllaceae
Jacquemontia Chois.	Convolvulaceae
Sphacele Benth.	Labiatae
Hesperocnide Torr. & Gray	Urticaceae
Sisyrynchium L.	Iridaceae

Pteridophytes* common to Hawaii and the Australasian-Malaysian region, but absent from America

Ophioglossum pendulum L.
Marattia Douglasii Baker
Schizaea australis Gaud.
Gleichenia longissima Blume
Acrostichum gorgoneum Kaulf.
Gymnogramme javanica Blume
Vittaria elongata Sw.
Polypodium Hookeri Brack.
P. samoense Baker
P. tamariscinum Kaulf.
P. lineare Thunb.
P. Spectrum Kaulf.
Phegopteris punctata Hillebr.
Aspidium aristatum Sw.
A. caryotideum Wall.
A. truncatum Gaud.
A. terminans Wall.
A. squamigerum Mann
Doodya media R. Br.
Asplenium Nidus L.
Asplenium normale Don
Asplenium varians Hook. & Grev.
Asplenium contiguum Kaulf.
A. caudatum Forst.
A. horridum Kaulf.
A. spathulinum Hook.
A. Adiantum-nigrum L.
A. polyphyllum Presl
Odontoloma repens Desv.
Microlepia strigosa Presl
M. tenuifolia Metten.
Pteris excelsa Gaud.
Trichomanes parvulum Poir.
T. meifolium Bory
Lycopodium serratum Thunb.
L. Phlegmaria L.
L. volubile Forst.

Pteridophytes common to Hawaii and America, but not found elsewhere

Asplenium fragile Presl
Pellaea ternifolia Fée

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* Nomenclature according to Hillebrand, Flora of the Hawaiian Islands.

UREDINALES OF CUBA

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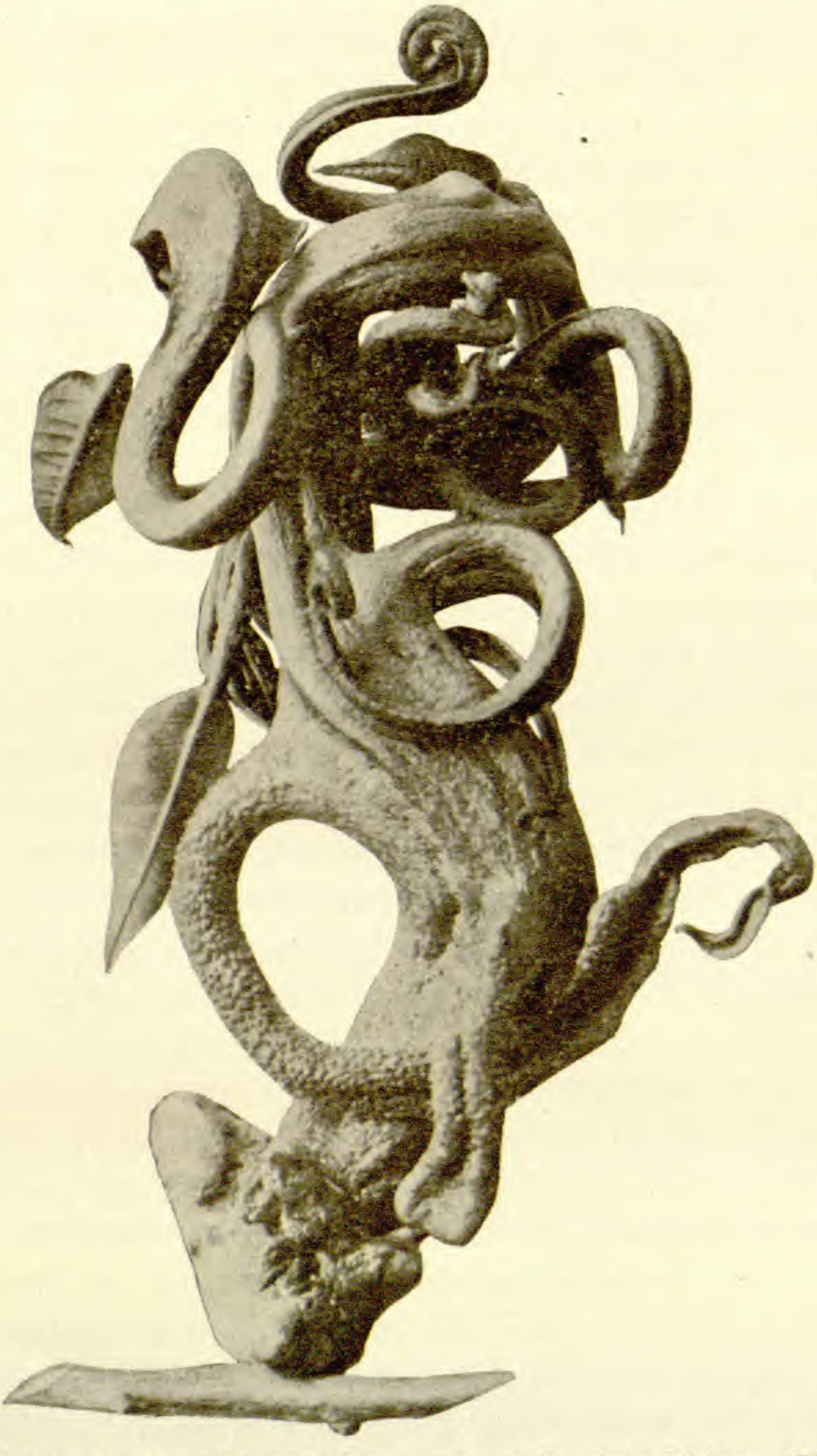

Shoot of *Rivina octandra* distorted by aecia of *Puccinia Rivinae.* Photo by Johnston, 1917.

INTRODUCTION

In a letter recently written by Professor F. S. Earle, the well-known botanist of Cuba, he says: "There is a very varied and interesting fungous flora here, but 'collecting' is not nearly as good as in the States. Field work is difficult, and many species are rare and local. I am curious to see how many rusts you have from here. There are really a great many, but it will take years to find them all." Professor Earle speaks with the knowledge of a mycologist, as he has to his credit some forty published papers dealing with mycological subjects, issued largely in the score of years between 1884 and 1904. Since becoming a resident of Cuba in 1904 he has occasionally gathered specimens of rusts, and he took a prominent part in the rediscovery of the rare *Prospodium plagiopus* at San Marcos in 1909–1910, as stated under that species.

The study of the Cuban Uredinales, or rusts, resulting in the present paper, has abundantly confirmed Professor Earle's statement. Although the first collections of rusts were made in Cuba, doubtless about 1840–45, by Ramon de la Sagra, a few added by Charles Wright in 1855–7, and by others from time to time, yet prior to 1915 the known Cuban rust flora would not have much exceeded half a hundred species. During 1915 the junior author, who had come to Cuba the previous year from a residence of three years in Porto Rico, began to gather material with the intention of publishing in Spanish a pamphlet on the rusts of Cuba for the use of students of the native flora. On February 22, 1916, he wrote to the senior author that "I have apparently so much new material, or at least new hosts, that I can not handle the subject properly under conditions here." He then proposed a joint paper on the rusts of Cuba, in English of course, and the presentation here made is the result.

A study of available material, together with all information which the authors have been able to collect, brings the present list of Cuban rusts up to 112 species, with 28 additional names of rusts belonging to the form-genera *Aecidium* and *Uredo*, which doubtless largely represent additional species whose life histories are too imperfectly known to permit of their reference to a true genus, Even many of the 112 true species have one or more spore forms yet to be discovered in order to make the life cycle fully known, and to permit a full technical description.

This first published list of Cuban rusts contains a fairly respectable and representative number of species, as is evident by comparing with the Porto Rican list of 110 true species and 42 others belonging to the form-genera *Aecidium* and *Uredo*. The rust flora of Porto Rico is the best known of all the West Indian islands. But Cuba is an island of thirteen times the area of Porto Rico. and with a more varied topography. It is evident, therefore, that the present showing must be accepted as only a beginning to the study of the Uredinales of Cuba.

There have been available for the present study about 470 collections, of which 57 were taken from specimens deposited in phanerogamic herbaria. These collections are represented in the Arthur herbarium. Only one species has been introduced into the list from published records, with no specimen available for examination, and that is the stem rust of wheat (no. 63), the best known and most cosmopolitan of all rusts.

The largest contributors toward material for a list of Cuban rusts have been the men employed since 1904 at the Cuban Agricultural Experiment Station (Estación Experimental Agronómica), located at Santiago de las Vegas, some score of miles from Havana. A large portion of the material has also been contributed by members of the expeditions sent to Cuba by the New York Botanical Garden, beginning in 1903. In addition to these some material has come from individual collectors, mostly while engaged in securing phanerogamic specimens.

Activity in the field of cryptogamic botany at the Cuban station began with the accession of Prof. F. S. Earle to the directorship of the station in 1904, and the contemporaneous and subsequent appointment of able botanists to other positions.

Professor Earle (1904–1906) gave chief attention to the fleshy fungi. Five collections of rusts are credited to him, representing as many species, and eight other numbers in association with other collectors. He retired from the station to his farm at Herradura in the Province of Pinar del Rio, eighty miles to the westward, where he still resides and maintains an interest in mycological studies.

Professor Charles F. Baker was chief of the department of botany in the Cuban station (1904–1907), and has nineteen collections of rusts credited to him, representing sixteen species, with three others as associate collector. He has always been an enthusiastic and tireless botanical explorer. From Cuba he went to the Museo Goeldi at Pará, S. A., then to the College of Agriculture at Los Baños, Philippines, of which he is now Dean.

Mr. Percy Wilson was assistant botanist from July to December, 1904, and collected rusts in connection with Messrs. Earle and Baker. His more extensive association with the rust studies on the island is spoken of later.

Sr. Miguel Zarragoitia y O'Donovan, credited in part with one collection, and with material from phanerogamic collections, was assistant to Professor Baker, and is now employed at Havana in clerical work in the Department of Agriculture.

Sr. Manuel Abarca y Vázquez, credited with two collections, was also assistant to Professor Baker. He is deceased.

Professor Mel. T. Cook, pathologist of the station (1904–1906), had his chief interest in galls produced by insects, but has six collections to his credit, representing five species. He is author of a work on Diseases of Tropical Plants (1913), and has for some years been plant pathologist of the New Jersey College of Agriculture and of the Experiment Station.

Professor Wm. T. Horne was pathologist at the Cuban Station (1904–1909), the first two years being assistant to Professor Cook, and has twenty-three collections of rusts, representing an equal number of species, credited to him. A few of these collections were made during a visit to Cuba in the year 1917. He is now professor of plant pathology in the University of California.

Mr. H. A. Van Hermann, assistant in horticulture (1904–1906), and later chief in horticulture (1914–1916), has the credit of two rust collections, and one other in association with Professor Baker. He was until recently chief in the Office of Vulgarization, and is owner of one of the largest nurseries in Cuba, and well acquainted with the Cuban flora.

Sr. P. Cardin, having one rust collection to his credit, has been Chief of the Department of Entomology at the Station since 1909.

Mr. S. C. Bruner is assistant pathologist at the station, having been appointed in 1916. He has one rust collection to his credit.

Mr. J. R. Johnston, the associate author of this paper, was pathologist to the station (1914–1917), and is now Chief, and especially in charge of pathology and microbiology, in the Office of Plant Sanitation at Havana. He is credited with 233 collections, representing 96 species, about five sevenths of the total number. He has also supplied much general information, especially in the way of field observations.

The above showing is an interesting indication of the botanical enthusiasm and devotion of the scientific men that have been employed by the Cuban Experiment Station. It becomes all the more noteworthy when it is understood that botanical collecting, and especially collecting of fungi, is not considered at all necessary at this station, and that no systematic effort is made to maintain a cryptogamic herbarium, although incidentally much material has accumulated.

The second group of contributors toward material for the present study has consisted of the men forming the expeditions sent out by the New York Botanical Garden, together with those joining these expeditions for a part of the time. Beside supplying specimens, much assistance has been rendered also by members of the garden staff in determining the hosts and in other services. There have also been much general good will and interest displayed toward this work.

The first expedition from the garden, in which rusts were secured, was in 1903. It was composed of Prof. F. S. Earle and Prof. L. M. Underwood, and was joined for a part of the time by Prof. E. W. D. Holway. Professors Earle and Holway sailed from New York on Feb. 26, and reached Santiago de Cuba on March 5, being joined there by Professor Underwood. After three days a coasting steamer was taken for Baracoa on the north shore, a region where Charles Wright collected in the fifties. Most of the collecting here was done on the slopes of El Yunque. After three days Professor Holway left the party (cf. Jour. N. Y. Bot. Gard. 4: 81–84. 1903), and took steamer for Gibara, and staging to the railway at Holquin, proceeded to Havana. On the way a few hours' stop was made at Santa Clara. In a few days he left for the north, arriving at Miami, Fla., on March 2. As a result of this trip Professor Holway contributed 42 specimens, representing 34 species of rusts. Messrs. Earle and Underwood left Baracoa on March 19, returning to Santiago de Cuba. After a few days at Alto Cedro, Professor Underwood sailed for Jamaica on March 27, and Prof. Earle for New York on the following day (cf. Jour. N. Y. Bot. Gard. **4**: 81–85. 1903). Together they contributed four specimens. The results of the expedition were disappointing, as the time fell in the dry period of an unusually dry season.

An expedition from the New York Garden spent the time between Feb. 21 and April 3, 1910, in Cuba. It was composed of Dr. and Mrs. N. L. Britton and Mr. Percy Wilson, and was joined at Havana by Prof. F. S. Earle. Most of the time was given to the Province of Santa Clara (cf. Jour. N. Y. Bot. Gard. **11**: 109–117. 1910), and incidentally eight specimens of rusts were secured.

A second expedition in 1910 spent Aug. 24 to Sept. 23, in western Cuba, exploring the Province of Pinar del Rio. It consisted of Dr. and Mrs. Britton and Dr. C. Stuart Gager, and was joined by Professor Earle (cf. Jour. N. Y. Bot. Gard. **11**: 226–236. 1910). Two specimens of rusts were secured.

In 1911 an expedition consisting of Dr. and Mrs. Britton and Mr. J. F. Cowell gave the time between Feb. 22 and the end of March, to an exploration of western and central Cuba (cf. Jour. N. Y. Bot. Gard. **12**: 89–95. 1911), securing one rust collection.

The most fruitful expedition in its bearing on the present rust study was in 1916, when Dr. and Mrs. Britton and Mr. Wilson devoted the time between Jan. 29 and March 28, largely to the Isle of Pines. They were joined for a few days by Brother León of the Colegio de la Salle, Havana (cf. Jour. N. Y. Bot. Gard. **18**: 64–71. 1916). Heretofore Mr. Wilson had taken an occasional specimen of rust, beginning when connected for a time in 1904 with the Cuban Experiment Station, and continuing to do so on his many subsequent trips to Cuba. But, having become especially interested in the rusts of the island while assisting in the critical determination of hosts, he gave considerable attention to these fungi during the present expedition. The result was that the two months' exploration yielded some 60 specimens of rusts, largely from the Isle of Pines, and largely collected by Mr. Wilson, part of which represent species, as well as hosts, not otherwise reported. This number is second only in size and importance to the contributions of Mr. Johnston, and considerably larger than the number secured during the first expedition to the island in 1903, when Professor Holway devoted special attention to the rusts, although under unfavorable conditions. Mr. Wilson's intimate knowledge of the phanerogamic flora of Cuba gave him unusual advantage as a collector of parasitic species. The whole insular list, as here presented, has also been made more valuable and accurate by Mr. Wilson's critical examination of the hosts of many collections. While engaged in this helpful study from time to time he detected rusts on the phanerogamic specimens in the herbarium of the New York Botanical Garden, and in this way added to the completeness of the presentation.

Other expeditions to Cuba from the New York Garden are not mentioned here, as they yielded no collections of rusts, although rusts have later been found on the phanerogamic specimens secured by some of them.

The names of a few persons who are credited with collections, and who were not connected at any time with the Cuban Experiment Station or the expeditions of the New York Botanical Garden, should be mentioned.

Ramon de la Sagra* came to Cuba from Spain in 1822 and became professor of botany in the university and director of the botanical garden at Havana. He took great interest in the flora of the island, collecting extensively all kinds of plants, and securing the assistance of many specialists in Europe and especially of P. de Candolle in the determination of the species. By his administrative ability and his numerous important writings he became famous throughout the island, and was assisted in his work by many local collectors. He projected and edited a monumental folio work in twelve volumes on the physical, political and natural

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* For brief biographical account by Ignatio Urban, see Symbolae Antillanae 3: 117–118. 1902.

history of Cuba, himself writing the general introduction and the part on climate and agriculture. In 1835 he went to Paris, taking with him his numerous collections. The cryptogams were placed in the hands of M. Montagne, and were described in the ninth volume of the folio work. The specimens are now in the Museum of Natural History at Paris. Only three collections of rusts are accredited to Sagra. Two of these, *Prospodium plagiopus* (*Puccinia plagiopus*), and *Puccinia poculiformis* (*P. graminis*) are cited in the volume by Montagne, and the third, *P. Anthephorae*, is said to have been collected by him. Sagra did not return to Cuba, and in 1871 died in Switzerland.

Mr. Charles Wright* spent nearly ten years in Cuba, between November, 1856, and July, 1867, collecting plants, chiefly phanerogams. The first expedition was confined to the province of Oriente and extended from Nov. 25, 1856, to about Sept. 1, 1857. Most of his fifteen numbers of rusts known to the authors were obtained during this period. Of the later ones only one has been seen by the authors, that on *Limnanthemum*, which was obtained in the province of Pinar del Rio in December, 1858, and is a form which has not been collected by any one else in America. The specimens bear little data, the date of collecting being confined to the years covering the expedition, rarely to the exact year, and the locality to "Cuba," or "in Cuba orientale," if any at all. The rusts form parts of the sets of fungi to be found in the Kew herbarium in London, and in the Herb. Curtis and also the Herb. Gray at Harvard University. The following is a list of the numbers known to the writers.†

275. "*Puccinia Asteris* Schw. on some unknown leaf," in Fungi Cubenses. The species is very rare in the tropics, and must be considered a doubtful determination for Cuba. Specimen has not been seen.

276. *Puccinia solida* B. & C. on "leaves of Compositae," in Fungi Cubenses, = *P. Synedrellae* P. Henn., on *Eleutheranthera ruderalis*. Type in Kew has been examined. See no. 109.

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* For brief biographical account, by Asa Gray, see Am. Jour. Sci. III. **31**: 12–17. 1886; and for an account of Wright's itinerary in Cuba, by L. M. Underwood, see Bull. Torrey Club **32**: 291–300. 1905.

† Most of the numbers are cited in the Fungi Cubenses, by M. J. Berkeley and M. A. Curtis, Jour. Linn. Soc. **10**: 280–391. 1869.

278. *Uromyces gemmatus* B. & C., on "the underside of leaves of *Convolvulus*," in Fungi Cubenses. Host is *Jacquemontia nodiflora*. Type in Kew has not been seen, but apparently the same collection in Herb. Curtis was studied. See no. 51.

279. *Uromyces appendiculatus* Lév., on "leaves of Leguminosae," in Fungi Cubenses. The collection has not been seen, but as the species is common in Cuba, it is doubtless correctly referred. See no. 44.

281. *Puccinia obliqua* B. & C., on "leaves of some plant resembling chickweed," in Fungi Cubenses. Fragment from Kew sent without number, which may be this one, has been examined. The host is reported from Kew as probably *Metastelma penicillatum*. See no. 89.

282. Cited as the second number under *Uromyces gemmatus* in Fungi Cubenses. Fragment of the collection from Kew, and also part of specimen in Herb. Curtis, have been examined. It is *Puccinia Gouaniae* Holw., II, on *Gouania polygama*. See no. 79.

283. *Puccinia heterospora* B. & C., on "the leaves apparently of some malvaceous plant," in Fungi Cubenses. The collection has not been seen, but it is probably correctly referred. See no. 81.

284. *Puccinia deformata* B. & C., on "*Olyra latifolia*, January," in Flora Cubenses. The type at Kew has not been examined, but there is no doubt of the correctness of the naming. See no. 58.

288. *Puccinia obliqua* B. & C. The number is not cited in Fungi Cubenses. A small leaf from the Kew herbarium has been examined and the collection appears to be the same as the one given above as 281. See no. 89.

480. The number is not cited in Fungi Cubenses. A specimen in Herb. Curtis, without data other than the number, has been seen and determined as *Ravenelia portoricensis* Arth., on *Cassia emarginata*. See no. 23.

596. *Puccinia deformata* B. & C., on *Olyra latifolia*. The number is not cited in Fungi Cubenses. A specimen in Herb. Curtis has been examined. See no. 58.

720. *Trichobasis euphorbiaecola* B. & C., on "leaves of some Euphorbia," in Fungi Cubenses. The fragment of this collection

from the Herb. Curtis, which has been seen, shows uredinia, and it is doubtless to be if is doubtless to be refererd to *Uromyces proeminens*. See no. 48.

727. *Trichobasis labiatarum* Lév., on "leaves of Labiatae," in Fungi Cubenses. A portion of the collection from the Herb. Curt. has been seen, but the species represented remains uncertain. It may be some species on *Leonotis*, *Hyptis*, or *Salvia*.

730. *Puccinia Cynanchi* Schw., on "the leaves and stem of some Asclepiad," in Fungi Cubenses. The collection has not been seen, although the type of *P. Cynanchi* from Surinam has been examined, and the Wright collection may well be the same species. It is now referred to *P. Gonolobi*. See no. 88.

756. *Aecidium Rivinae* B. & C., on "racemes of *Rivina octandra*," in Fungi Cubenses. The collection has not been seen, but there is no doubt regarding the names. The species is now referred to *Puccinia Rivinae* (B. & C.) Speg. See no. 74.

929. A collection in the Herb. Curtis, which has been examined, is labelled *Aecidium Nymphaearum* DC., on *Limnanthemum Grayanum* Griseb., and doubtless correctly so. The species is now referred to *Puccinia Scirpi*. See no. 69.

Mr. Otto E. Jennings, accompanying a natural history expedition* from the Carnegie Museum of Pittsburgh, Pa., collected in the Isle of Pines from May 5 to May 26, 1910. One rust collection (cf. no. 89), and one phanerogamic specimen bearing a rust (cf. no. 60), were obtained at this time.

Beside the above collectors of fungi, who have enriched our knowledge of the rust flora of Cuba, there are some fourteen botanists, whose names appear in the following list in connection with phanerogamic specimens from the island, found to bear rusts. Altogether half a hundred botanists are represented as field collectors in the present account of the rusts of Cuba, to whom is due the credit of making material available as a basis for this first account of the Cuban rusts.

Comparison of the list as it now stands with the list of rusts for Porto Rico, bringing the last published account of the latter up to date in order to make the two more accurately comparable, shows a close agreement in the number and kind of genera and in

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* For some account of the expedition and of the topography and floristic conditions on the Isle of Pines, see Am. Fern Jour. 1: 129–136. 1911; and Ann. Carnegie Mus. 11: 19–290. 1917.

the number of species in each genus, as well as in the comparative numbers of long- and short-cycle forms. The differences are only such as might be expected from incomplete exploration. The greater total number of species now known for Porto Rico is chiefly accounted for by the greater number of unconnected *Uredo*-forms, which have been found in that island. Whether this array of forms still under the genus *Uredo* indicates that the flora of Porto Rico is more tropical than that of Cuba, or whether it is better known for such forms, is doubtless debatable.

A comparison of the Cuban with a continental area presents marked differences. The most instructive comparison at present possible is that with Guatemala. A recent study of the Uredinales of Guatemala, not yet published, gives a list of species about as complete for that country, as that here presented for Cuba. Nearly a third of the area of Guatemala, especially the northern part in the Department of Peten, is unrepresented by collections. The remainder of the country is of about the area of Cuba, but of a more varied topography, having many high mountains. The climate is doubtless somewhat more tropical that that of Cuba, although northern species find congenial conditions in the high altitudes. Thus the genera *Melampsora*, *Melampsoridium*, *Pucciniastrum*, *Uropyxis*, and *Phragmidium*, not represented in Cuba or Porto Rico, are to be found there. Also the forms under *Uredo* are only about one half those in Cuba and one third those in Porto Rico. Both classes of facts indicate certain less tropical aspects of the flora, but nevertheless, they are aspects that may have to do with the boreal features of the mountainous part of the flora. There are, however, three genera, that is, treating the correlated *Uromyces* and *Puccinia* as a single genus, which can be taken as comparable factors to indicate differences between the insular and continental floras.

NUMBER OF SPECIES OF RUSTS

	Cuba	Porto Rico	Guatemala
Coleosporium	5	3	8
Ravenelia	9	10	20
Puccinia-Uromyces	76	74	150
	90	87	178

The table indicates the presence in Cuba or in Porto Rico of only half as many species in each of the three genera, *Coleosporium*, *Ravenelia*, and *Puccinia-Uromyces*, or in all combined, as occur in Guatemala. The difference in abundance may be ascribed to the differences between insular and continental conditions, or to the diversity of topography, or to both factors combined.

The only genera represented in Cuba, not found in the other West Indian islands, or the nearby continent, are *Sphaerophragmium* and *Uromycladium*, both based somewhat doubtfully upon material needing further field observations and study. The seemingly greater similarity to the rust flora of southern Florida and the regions bordering the Gulf of Mexico, than is shown by the rust flora of Porto Rico, has been previously pointed out,* as well as the surprisingly large number of short-cycle species. To go into a more detailed comparison of the Cuban rust flora with that of other regions is not likely to be particularly profitable at the present time owing to the imperfect data available, not only for Cuba, but even more so for most regions with which it might be compared.

In the following enumeration twelve species are described as new, and five species are transferred to other genera, making new combinations. Most of the changes in genera are due to finding additional spore forms, but some are in the nature of quite new discoveries, as in the case of *Uromyces cristatus*, which was embalmed under the name of *Uredo*, although not itself uredinial, or belonging to a species having a uredinial stage.

The list introduces 15 species new to the North American flora, of which 10 species are exclusively Cuban, so far as present knowledge extends, the others being mostly South American forms.

In conclusion it may be said that the present enumeration of 140 species of Cuban rusts must be considered only the basis for a thoroughly scientific and economic exploration of the island for this group of obligate parasites. When sufficient taxonomic data are finally accumulated the still more interesting task of studying the species in relation to their distribution, the abundance from year to year, their origin on the island, and their relation to economic problems, can be taken up with interest and profit. The

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* Arthur, Rusts of the West Indies. Torreya **17**: 24–27. 1917.

study of the rusts opens a field that is likely to prove very attractive to Cuban scholars, as it has been to others not so familiar with insular conditions.

Map of Cuba, with scale of miles, showing the provinces: *A*, Pinar del Rio; *B*, Habana; *C*, Matanzas; *D*, Santa Clara; *E*, Camagüey; *F*, Oriente; *G*, Isle of Pines. Some of the principal cities and towns are also indicated.

The microscopical study of the material on which this paper is based was done in the laboratory of the botanical department of the Purdue University Agricultural Experiment Station at Lafayette, Indiana, as part of the preliminary work on the rust portion of the North American Flora. Thanks are due to Pro- H. S. Jackson, chief of the department, and to his assistants, for their assistance.

Family: **Coleosporiaceae**

1. COLEOSPORIUM ELEPHANTOPODIS (Schw.) Thüm. Myc. Univ. 953. 1878.

ON CARDUACEAE:

Elephantopus mollis H. B. K., El Yunque, Baracoa (Prov. Oriente), March 12, 1903, *Holway;* La Cunagua, Isle of Pines, Feb. 19, 1916, II, *Britton, Britton & Wilson 14554;* San Pedro, Isle of Pines, Feb. 12–March 22, 1916, II, *Britton, Britton & Wilson 15808;* Baracoa (Prov. Oriente), April 14, 15, 1916, *Johnston 504, 507*.

The species is heteroecious, having aecia on leaves of pine. In tropical regions it is doubtless maintained by the repeating urediniospores. It occurs in Porto Rico, Jamaica, and St. Vincent, but is more abundant on the continents, both north and south.

2. COLEOSPORIUM VERNONIAE Berk. & Curt. Grevillea **3**: 57. 1874.

ON CARDUACEAE:

Lachnorhiza piloselloides A. Rich., San Pedro, Isle of Pines, Feb. 12–March 22, 1916, II, *Britton & Wilson 14713*.

The first record of the species for the West Indies. The host is also new for the species. Northward aecia occur on pine leaves.

3. COLEOSPORIUM IPOMOEAE (Schw.) Burr. Bull. Ill. Lab. Nat. Hist. **2**: 217. 1885.

ON CONVOLVULACEAE:

Ipomoea cathartica Poir. (*I. acuminata* R. & S., *Pharbitis cathartica* Choisy), Rincón (Prov. Habana), Sept. 26, 1915, *Johnston 156*.

Ipomoea mutabilis Lindl. (*I. Learii* Meissn. not Paxton) Vedado (Prov. Habana), Dec. 6, 1916, *Johnston 926;* Consolación del Sur (Prov. Pinar del Rio), March, 1917, II, *Horne*.

Ipomoea stolonifera (Cyrill.) Poir., Siguanea, Isle of Pines, Feb. 26, 1916, II, *Britton, Britton & Wilson 14936*.

Also found in the phanerogamic herbarium at the N. Y. Bot. Garden on *Jacquemontia tamnifolia* (L.) Griseb., collected by *Eugenio Cuesta 329*, at Pinar del Rio, December, 1911.

The species is heteroecious, with aecia on leaves of pines, but in tropical regions is probably maintained by the repeating urediniospores. In the West Indies it is also known from Porto Rico and St. Croix, but is more common on the continents to the north and south.

4. COLEOSPORIUM PLUMIERAE Pat. Bull. Soc. Myc. Fr. **18**: 178. 1902.

ON APOCYNACEAE:

Plumiera emarginata Griseb., Limones Cienfuegos (Prov. Santa Clara), Nov. 4, 1915, II, *Johnston 216;* Marianao (Prov. Habana), Oct. 31, 1915, II, *Johnston 236*, Feb. 6, 1916, *Johnston 441;* Caleta Cocodrilos, Isle of Pines, March 8, 1916, II, *Britton, Wilson & León 15300*.

Plumiera obtusa L., Santiago de las Vegas, June 21, 1906, *Cook*.

Plumiera rubra L., Santiago de las Vegas, Sept. 4, 1904, *Baker 1378*, May 9, 1906, *Baker* (Barth. Fungi Columb. *2217*), April 4, 1906, *Horne 18*, June 21, 1906, *Cook;* Limones Cienfuegos (Prov. Santa Clara), Nov. 4, 1915, II, *Johnston 227.*

This West Indian rust is undoubtedly heteroecious, but with aecia yet unknown. The telia are rarely produced and the continuance of the species is probably by urediniospores. It is also known from Porto Rico and Guadeloupe.

5. COLEOSPORIUM EUPATORII Arth. Bull. Torrey Club **33**: 31. 1906.

ON CARDUACEAE:

Eupatorium macrophyllum L., El Yunque, Baracoa (Prov. Oriente), March 12, 1903, II, *Holway;* Taco Taco (Prov. Pinar del Rio), Sept. 17, 1916, II, *Johnston 875.*

This species is undoubtedly heteroecious, like other species of the genus. It is at present known only in the uredinial stage, and there is much likelihood that when more fully studied may be united with earlier named species on other hosts. It was also detected in the phanerogamic herbarium of the N. Y. Bot. Garden, on same host from Trinidad Mountains (Prov. Santa Clara), March 6, 1910, II, *Britton & Wilson 5134.* It is also known from Guatemala, Nicaragua, and from South America.

Family: **Uredinaceae** (**Melampsoraceae**)

6. PHAKOPSORA VITIS (Thüm.) Syd. Hedwigia Beibl. **38**: 141. 1899.

Physopella Vitis Arth. Résult. Sci. Congr. Bot. Vienne 338. 1906.

ON VITACEAE:

Vitis vinifera L., Havana, March 21, 1903, *Holway;* Santiago de las Vegas, May 13, 1916, *Johnston 701.*

This imperfectly known rust has not been found on any native grape in America. The collections are treated under the name *Vitis vinifera*, but no adequate examination of the cultivated hosts has been made to substantiate this assignment. The species is abundant in Porto Rico and Jamaica, as well as in the warmer parts of North and South America and Japan, and is often quite injurious to cultivated grape vines.

7. PHAKOPSORA VIGNAE (Bres.) Arth. Bull. Torrey Club **44**: 509. 1917.

Uredo Vignae Bres. Rev. Myc. **13**: 66. 1891.
Uredo concors Arth. Mycologia **7**: 330. 1915.
Physopella concors Arth. Mycologia **9**: 60. 1917.

ON FABACEAE:

Genus and species undet., Herradura (Prov. Pinar del Rio), March, 1917, II, *Horne*.

Only uredinia of this species are yet known. The type of *Uredo Vignae* came from St. Thomas and of *U. concors* from Porto Rico. The species will doubtless be found eventually on other West Indian islands.

8. PHAKOPSORA AESCHYNOMENIS Arth. Bull. Torrey Club **44**: 509. 1917.

Uredo Aeschynomenis Arth. Bot. Gaz. **39**: 392. 1905.
Physopella (?) *Aeschynomenis* Arth. N. Am. Flora **7**: 104. 1907.

ON FABACEAE:

Aeschynomene americana L., Santiago de las Vegas, Nov. 6, 1916, II, *Johnston 920*.

Only uredinia of this species are yet known. It occurs also in Porto Rico, as well as in Mexico and South America.

9. CEROTELIUM FICI (Cast.) Arth. Bull. Torrey Club 44: 509. 1917.

Uredo Fici Cast.; Desmaz. Pl. Crypt. *1662*. 1848.
Uredo ficicola Speg. Anal. Soc. Ci. Argent. **17**: 120. 1884.
Uredo ficina Juel, Bih. K. Sv. Vet.-Akad. Handl. **23^{10}**: 25. 1897.
Uredo moricola P. Henn. Hedwigia **41**: 140. 1902.
Physopella ficina Arth. N. Am. Flora **7**: 103. 1907.
Physopella Fici Arth. N. Am. Flora **7**: 103. 1907.
Kuehneola Fici Butler, Ann. Myc. **12**: 76. 1914.

ON ARTOCARPACEAE:

Ficus Carica L., Santiago de las Vegas, March 13, 1906, *Horne 15*, July 21, 1906, *Cook;* Limones Cienfuegos (Prov. Santa Clara), Nov. 4, 1915, II, *Johnston 215;* Omaja (Prov. Oriente), March 30, 1916, II, *Johnston 547;* Paso Estancia (Prov. Oriente), May 3, 1916, II, *Johnston 685*.

Ficus Combsii Warb., San Diego de los Baños (Prov. Pinar del Rio), Feb. 7, 1915, II, *Johnston 175;* Minas (Prov.

Camagüey), Dec. 2, 1915, *Johnston 371;* Marianao (Prov. Habana), Feb. 6, 1916, II, *Johnston 443*.

The full life history of this rust is not known. No telia have been found in America, and no pycnia anywhere. It is cosmopolitan throughout the tropics, but in the West Indies is only recorded from Cuba and Porto Rico.

10. CEROTELIUM GOSSYPII (Lagerh.) Arth. Bull. Torrey Club **44**: 510. 1917.

Aecidium desmium Berk. & Br. Jour. Linn. Soc. **14**: 95. 1873.
Uredo Gossypii Lagerh. Jour. Myc. **7**: 48. 1891.
Kuehneola Gossypii Arth. N. Am. Flora **7**: 187. 1912.

ON MALVACEAE:

Gossypium acuminatum Roxb., Santiago de las Vegas, March, 1903, II, *Underwood & Earle 159*.

Gossypium sp., Santiago de las Vegas, August, 1904, II, *Baker* (Barth. Fungi Columb. *2489*).

This rust is still imperfectly known, as the pycnia have not been found. It is rather common upon wild and cultivated cottons in both hemispheres, but in the West Indies is reported only from Cuba and Porto Rico.

11. KUEHNEOLA MALVICOLA (Speg.) Arth. N. Am. Flora **7**: 187. 1912.

Uredo malvicola Speg. Anal. Soc. Ci. Argent. **17**: 124. 1884.
Uredo Hibisci Syd. Hedwigia Beibl. **40**: 128. 1901.

ON MALVACEAE:

Hibiscus syriacus L., Santiago de las Vegas, March 14, 1906, II, *Horne 14*.

Malvaviscus Sagreanus A. Rich., Santiago de las Vegas, Oct. 23, 1906, II, *Johnston 904*.

An imperfectly known species, the pycnia not having been seen. It is not an uncommon species in the southern United States, Central America, and parts of South America, but from the West Indies only one other collection is known, which was obtained by Whetzel & Olive in Porto Rico, on *Malache scabra* (Mycol. **9**: 63. 1917).

12. **Cronartium notatum** (Arth.) comb. nov.

Uredo notata Arth. Mycologia **9**: 89. 1917.

ON MALPIGHIACEAE:

Byrsonima crassifolia (L.) H. B. K., San Marcos (Prov. Santa Clara), Nov. 18, 1915, II, *Johnston 186;* Las Tunas (Prov. Oriente), March 29, 1916, ii, III, *Johnston 545*.

The rust has previously only been known from Porto Rico, and in the uredinial stage. The fine specimen obtained by Mr. Johnston at Las Tunas provides the following characters for the telial stage.

Telial columns hypophyllous, somewhat grouped, rather numerous, cylindrical, moderately stout and short, 1–1.5 mm. long, 90–145 μ broad, chestnut-brown; teliospores oblong, 17–26 by 45–64 μ, obtuse or truncate at both ends; wall yellow, 2–3 μ thick, smooth.

The species differs from *C. Byrsonimatis* P. Henn., known from South America on *B. coccolobifolia*, by the somewhat larger urediniospores, with their walls less thickened at apex, the conspicuous development of imbricated paraphyses, and by the thicker-walled teliospores.

It might be well to call attention to the possibility that this rust, instead of being heteroecious, as in species of temperate regions, may be autoecious. There is an aecial form in Mexico on this host, first described as *Endophyllum singulare* D. & H., which from its morphology may well belong here.

13. **Cronartium Wilsonianum** sp. nov.

ON VITACEAE:

Cissus rhombifolia Vahl, San Juan, Isle of Pines, March 15, 17, 1916, II, III, *Britton, Britton & Wilson 15552*.

Uredinia chiefly hypophyllous, numerous, scattered, sometimes crowded in small groups, round, small, 0.2 mm. or less in diameter, dehiscent by a central rupture, soon wide open, pulverulent, very pale straw-color; paraphyses apparently free, peripheral, incurved, clavate, 13–15 by 35–40 μ, the wall very pale yellow or colorless, thin, about 1 μ, smooth; urediniospores broadly ellipsoid or obovoid, 18–21 by 24–27 μ; wall pale yellow or colorless, thin, 1.5 μ or less, sparsely and very sharply and prominently echinulate, the pores obscure.

Telial columns hypophyllous, 2–3 mm. in length, about 70 μ thick, filiform, dark chestnut-brown; teliospores terete or fusiform, 10–13 by 48–61 μ, usually obtuse at both ends; wall pale cinnamon-brown, thin, about 1 μ, smooth.

A distinctive species, appearing in abundance over the large leaves of the host. The form of the uredinial envelope is especially interesting, free paraphyses being a novelty in the genus.

A uredinial specimen on the same host was collected by Lagerheim near Quito, Ecuador, June, 1890, which was given a herbarium name by the collector not established by description or publication.

It is doubtful if this is a heteroecious rust, like the members of the genus occurring in northern regions. Information to complete the life history will be of special interest.

The species is named in recognition of the botanical services of Mr. Percy Wilson of the N. Y. Botanical Garden in making known the flora of Cuba, and especially the rust flora. Mr. Wilson's numerous collections of Cuban rusts, made largely in 1916, added much to previous knowledge, and his patient and critical examination of the hosts for most of the collections in this list has added immensely to the accuracy and value of their citation.

14. **Cionothrix Cupaniae** sp. nov.

ON SAPINDACEAE:

Cupania americana L., Ceballos (Prov. Camagüey), March 24, 1916, *Johnston 668.*

Cupania glabra Sw., Paso Estancia (Prov. Oriente), May 3, 1916, *Johnston 679, 694* (type), *696.*

Telial columns hypophyllous, in groups on discolored and somewhat thickened areas, 3–5 mm. across, a mammiform swelling forming the base from which each column arises, cylindrical, short, rigid, 0.3–0.5 mm. long, 19–35μ wide, colorless; teliospores fusiform, 7–15 by 40–65μ, tapering at both ends; wall colorless, thin, 1μ or less, colorless.

No indication of uredinia were found on the type, *no. 694*, or other collections, and for this reason the species is issued under the short-cycle genus, *Cionothrix*, even though pycnia were not seen. Sections of young telia show the young catenulate spores arising in a layer, like cylindrical hyphae with transverse septa, and with no indication of peridium or paraphyses.

Family: **Aecidiaceae** (**Pucciniaceae**)

15. RAVENELIA INDIGOFERAE Tranz. Hedwigia **33**: 369. 1894.

ON FABACEAE:

Indigofera suffruticosa Mill. (*I. Anil* L.), Baracoa (Prov. Oriente), March 9, 1903, II, *Holway;* Santiago de las Vegas, March 15, 1905, II, III, and April 5, 1906, II, iii, *Horne*, Jan. 15, 1907, II, III, *Baker 3055* (Barth. Fungi Columb. *2475*), July 15, 1915, II, *Johnston 157;* Consolación del Sur (Prov. Pinar del Rio), Feb. 2, 1915, II, *Johnston 141;* Santiago de las Vegas, Nov. 29, 1917, II, III, *Johnston 953*.

The species, like all other rusts referred to the genus *Ravenelia* in this paper, is autoecious, the life cycle including pycnia, uredinia, and telia, although no pycnia have yet been seen in this species. The other West Indian islands where it has been found are Jamaica, Porto Rico, and Bermuda. It also occurs in Mexico and South America.

16. RAVENELIA PISCIDIAE Long, Jour. Myc. **12**: 234. 1906.

ON FABACEAE:

Ichthyomethia Piscipula (L.) A. S. Hitchc., Ensenada de Siguanea, Isle of Pines, Feb. 18, 1916, II, III, *Britton, Wilson & Selby 14533*, Feb. 25, 1916, II, III, *Britton & Wilson 14849;* San Juan, Isle of Pines, March 15, 17, 1916, II, III, *Britton, Britton & Wilson 15449*.

This rust heretofore has been known only from southern Florida. No pycnia have yet been discovered for the species.

17. RAVENELIA LONCHOCARPI Lagerh. & Diet. Hedwigia **33**: 46. 1894.

ON FABACEAE:

Lonchocarpus latifolius H. B. K., Ceballos (Prov. Camagüey), March 24, 1916, II, *520, 530*, April 6, 1916, II, *627, 665, 666;* Baracoa (Prov. Oriente), April 14, 1916, II, *638*, all by *Johnston*.

Heretofore the species has been known only from Brazil, and on *Lonchocarpus campestris*. The ample material supplied by Mr. Johnston shows an abundance of uredinia, agreeing closely with the uredinial part of the original description, no Brazilian specimen having been seen. No pycnia or telia could be detected.

18. RAVENELIA SILIQUAE Long, Bot. Gaz. **35**: 118. 1903.

ON MIMOSACEAE:

Vachellia Farnesiana (L.) W. & A. (*Acacia Farnesiana* Willd.), Santiago de Cuba, April 30, 1916, II, *Johnston 684.*

This collection, the first one seen from the West Indies, shows the usual abundance of uredinia on the pods. The species also occurs in Central Mexico. No pycnia or telia are known for it, and it has until recently been taken only on the fruit of the host. Long (Bot. Gaz. **64**: 64. 1917) reports it on branches and leaves.

19. RAVENELIA PITHECOLOBII Arth. Bot. Gaz. **39**: 394. 1905.

ON MIMOSACEAE:

Pithecolobium tortum Mart., Sierra de los Ceballos, Isle of Pines, March 2, 1916, III, *Britton & Wilson 15358.*

This is the first record of the species for the West Indies, being previously known from southern Florida and Mexico, and is also the first record for this species of host. The pycnia of the species are yet unknown.

20. RAVENELIA LYSILOMAE Arth. Bot. Gaz. **39**: 392. 1905.

Dendroecia Lysilomae Arth. Résult. Sci. Congr. Bot. Vienne 340. 1906.

ON MIMOSACEAE:

Lysiloma bahamensis Benth., Punta Sabanilla, Cienfuegos Bay (Prov. Santa Clara), Feb. 24, 1910, III, *Britton, Earle & Wilson 4586.*

This collection shows telia but no uredinia, although a few urediniospores are present. The species was originally placed in the genus *Dendroecia* on evidence similar to this. Dietel states (Beih. Bot. Centr. **20**: 375. 1906) that well-developed uredinia were found by him upon the type collection, made by E. W. D. Holway at Iguala, Mexico, on *L. tergemina.* A more ample portion of this collection than was originally available has enabled the senior author to confirm the statement made by Dietel. On this evidence, which completes the life history, the species is returned to the genus *Ravenelia,* where it evidently belongs. The above collection gives the first station known outside of Mexico, and adds another species of host.

21. RAVENELIA HUMPHREYANA P. Henn. Hedwigia **37**: 278. 1898.
Ravenelia pulcherrima Arth. Bot. Gaz. **39**: 395. 1905.
ON CAESALPINIACEAE (CASSIACEAE):
Caesalpinia bahamensis Lam. (*C. Rugeliana* Urban), Santa Clara to Loma Cruz (Prov. Santa Clara), March 22, 1911, II, *Britton, Britton & Cowell 10225* (host no. *10224*).
Poinciana pulcherrima L. (*Caesalpinia pulcherrima* Sw.), Holguin (Prov. Oriente), March 17, 1903, II, III, *Holway;* Soledad (Prov. Santa Clara), Nov. 4, 1915, II, *Johnston 221;* Santiago de las Vegas, Nov. 3, 1917, II, *Johnston 950.*

The pycnia for this species have not yet been found. Type collection for the species came from Mexico. The species is known also from Jamaica and Guatemala. The first host named is a new one.

22. **Ravenelia cubensis** sp. nov.
ON CAESALPINIACEAE:
Cassia robinaefolia Benth., Cacocum (Prov. Oriente), April 6, 1916, *Johnston 531.*

Uredinia amphigenous, scattered or somewhat grouped, round, 0.2–1 mm. across, subepidermal, rather tardily naked, cinnamon-brown, pulverulent, ruptured epidermis conspicuous; paraphyses none; urediniospores ellipsoid or obovoid, 16–19 by 23–26μ; wall golden- or light cinnamon-brown, rather thin, 1–2μ, thicker at apex, 3–6μ, moderately and finely echinulate, the pores 4, equatorial.

Telia unknown.

This rust is so evidently a *Ravenelia*, that it is unhesitatingly described as such, although no telia are yet known.

23. RAVENELIA PORTORICENSIS Arth. Bull. Torrey Club **31**: 5. 1904.
ON CAESALPINIACEAE:
Cassia emarginata L., without locality or date, II, *Charles Wright 480;* Santiago de Cuba (Prov. Oriente), March 6, 1903, II, *Holway;* same, April 30, 1916, II, *Johnston 683.*

Heretofore this rust has been known chiefly from Porto Rico. One collection is recorded from Jamaica, and Mr. Percy Wilson has communicated two specimens found in the phanerogamic herbarium of the New York Botanical Garden, one from Barahona, St. Domingo, May, 1910, II, *Pater Fuertes 192*, and the other from San Michel, Hayti, Aug. 5, 1905, ii, *Nash & Taylor 1393*. A part of a collection made by Charles Wright in Cuba, bearing no data except the number 480, has been sent by Dr. W. G. Farlow from the Curtis collection, which proves to be the uredinial stage of this species. All collections of the species so far seen have been found to be on *Cassia emarginata*.

24. **Uromycladium** (?) **cubense** sp. nov.

ON MIMOSACEAE:

Mimosa pigra L. (*M. asperata* L.), Soledad Cienfuegos (Prov. Santa Clara), Nov. 6, 1915, *Johnston 191*.

Telia amphigenous, emaculate, scattered, oval or oblong, 0.2–0.4 by 0.5–1 mm., subcuticular, soon naked, pulverulent, chestnut-brown, ruptured cuticle conspicuous, teliospores triangular-obovate, or short-pyriform, length and breadth the same, 15–18 μ, remaining attached to pedicel in groups of 1–4 (usually 2); wall at sides colorless, smooth, and thin, 1 μ, above chestnut-brown, finely and closely verrucose, 1.5–2 μ thick; pedicel in upper part firm, remaining attached to spores, chestnut-brown, 7–9 μ broad, 7–10 μ long, the wall about 1.5 μ thick, part below colorless, thin-walled, collapsing and readily falling away.

This unique rust does not drop readily into any genus. It is placed tentatively in *Uromycladium*, although the spores are not clearly arranged in series on the pedicel, and no cyst is present. There are other variations, as for instance, the lack of an evident germ pore, as well as the absence of uredinia and pycnia. Moreover, *Uromycladium* has heretofore been accounted a peculiarly Australian genus.

25. CALLIOSPORA FARLOWII Arth. Bot. Gaz. **39**: 391. 1905.

ON FABACEAE:

Parosela domingensis (DC.) Heller (*Dalea domingensis* DC.), Vento (Prov. Habana), Aug. 26, 1905, *Baker 3312*.

This short-cycle rust, having pycnia and telia, is known only on the one species of host, and only from Cuba and Mexico.

26. TRANZSCHELIA PUNCTATA (Pers.) Arth. Résult. Sci. Congr. Bot. Vienne 340. 1906.

Aecidium punctatum Pers. Ann. Bot. Usteri **20**: 135. 1796.

Puccinia Pruni-spinosae Pers. Syn. Fung. 226. 1801.

ON AMYGDALACEAE:

Amygdalus Persica L. (*Prunus Persica* Sieb. & Zucc.), Santiago de las Vegas, Sept. 27, 1915, II, *Johnston 166*.

The collection shows only uredinia, and these not in much abundance. The species is heteroecious, having its aecia on *Anemone*, *Hepatica*, and *Thalictrum*. It is a common rust throughout tropical and temperate regions of both hemispheres, but only three collections have been seen from the West Indies, one each from Cuba, Porto Rico, and Bermuda, and all being uredinia and on same host.

27. PROSPODIUM APPENDICULATUM (Wint.) Arth. Jour. Myc. **13**: 31. 1907.

Puccinia appendiculata Wint. Flora **67**: 262. 1884.

ON BIGNONIACEAE:

Stenolobium stans (L.) D. Don (*Tecoma stans* Juss.), Holguin (Prov. Oriente), March 17, 1903, *Holway*, Havana, March 22, 1903, *Holway* (Barth. N. Am. Ured. *724*); Santiago de las Vegas, Feb. 28, 1916, *Johnston 469*.

The species is common in tropical regions, and is autoecious, possessing pycnia, uredinia, and telia. The only other West Indian island represented is Porto Rico.

28. PROSPODIUM PLAGIOPUS (Mont.) Arth. N. Am. Flora 7: 162. 1912.

Puccinia plagiopus Mont. Pl. Cell. Cuba 294. 1842.

ON BIGNONIACEAE:

Tecoma lepidota (H. B. K.) DC., San Marcos (Prov. Santa Clara), without date, II, iii (*Ramon de la Sagra?*); same locality, Sept. 26, 1910, II, *F. S. Earle;* Palm barrens east of Guanabacoa (Prov. Habana), April 2, 1910, II, iii, *Britton, Earle & Wilson 6264* (host no. *6257*).

Tecoma pentaphylla (L.) Juss., Santo Domingo (Prov. Santa Clara), Nov. 7, 1915, II, *Johnston 183;* Havana, Feb. 26, 1916, *Johnston 491;* San Juan, Isle of Pines, March 15, 17, 1916, II, *Britton, Britton & Wilson 15471*.

The species is an autoecious one with uredinia and telia, preceded undoubtedly by pycnia, which have not yet been seen. It was described originally by C. Montagne, who prepared the volume of cryptogams which was part of the encyclopedic work on the physical, political, and natural history of Cuba, issued irregularly in parts about 1840–65, both from Paris and Havana. The volumes 9–12, treating of natural history, were edited and in part written by Ramon de la Sagra, volume nine being Montagne's treatment of the cryptogams, the material for which is generally understood to have been collected by de la Sagra. An excellent description of this species was given by Montagne under the name *Puccinia plagiopus*, together with figures of both kinds of spores, and also of the coriaceous leaflet and peltate hair of the host. The reason for figuring the unusual form of hairs was not to help in the identification of the host, which was said to be wholly unknown (*mihi prorsus ignota*), but because the writer thought he had discovered a remarkable metamorphosis, by which the peltate hair became the envelope surrounding each group of spores. The circle of paraphyses bounding each sorus forms a unique fimbriated structure supported on a pedicel-like base, and easily detachable as a whole, having about the size and color of the plant-hairs, so that the error of interpretation was a natural one.

No further information regarding this rust became available until the original collection was restudied by Monsieur P. Hariot of the Paris Museum (Bull. Soc. Myc. Fr. **7**: 196. 1891) half a century later. After an extended discussion he expresses the opinion that it doubtless constitutes the basis of a new genus related to *Puccinia*, *Phragmidium*, and *Uropyxis*, having urediniospores surrounded by a membrane, teliospores with a *Uropyxis*-like, gelatinous covering, and "no paraphyses." However, with only one specimen in the herbarium he hesitates to establish the genus (*il serait téméraire de se prononcer*). The paraphysate structure, which Montagne thought might be a transformed hair of the host, is described by Hariot as a hyaline halo in form of a collar with wavy edge, but he does not associate the term paraphyses with it, hence his nascent genus is said to be without paraphyses.

Hariot attempted to advance the identity of the host by suggesting that the nature and form of the hypophyllous hairs indicated a member of the Oleaceae, a statement followed in Sydow's Monographia Uredinearum (1: 345. 1902).

When working on the second part of the rust portion of the

North American Flora the senior author observed the peculiarity of appendaged pedicels described by Montagne, and thought the species might be a member of the newly erected genus *Prospodium*. An appeal was made to M. Hariot in March, 1909, for a fragment of the original Cuban collection, which was most kindly sent, and which confirmed the suggestion. Some months previous to this the Pflanzenfamilien of Engler & Prantl had been searched for some illustration which would give the kind of leaf or leaflet figured by Montagne, without much success, although similar hairs were illustrated under Bignoniaceae. In January, 1909, the herbarium of the N. Y. Bot. Garden was searched for a similar purpose, and again with no better success. Going from New York to Washington, the National Museum yielded two sheets, possibly two collections, from Cuba by Charles Wright, made in 1865, locality not given, labelled *Tecoma lepidota* DC., which showed compound leaves with leaflets that quite well answered to the requirements in Montagne's record. With this aid the assistance of Prof. F. S. Earle, a sometime student of the rusts, was sought. Prof. Earle was at that time stationed at Jovellanos, about 80 or 100 miles west of San Marcos, the type locality. A statement of the situation, with a drawing of the leaf as given by Montagne, was sent in February, 1909. A hasty visit to the locality made by Prof. Earle in April, 1909, yielded no results, but in September, 1910, he transmitted two leaflets from "a Catalpa-like shrub with 5-parted leaves," and the statement that "at last I am able to send you what I take to be your long desired rust from the type locality; I chanced to stop with friends at San Marcos today [Sept. 26] and found one shrub with a few infected leaves." This collection gave uredinia only, but there was little doubt about its being the Montagne species. The host was still unnamed. In only a few weeks, however, an ample collection with telia and uredinia was received from Dr. N. L. Britton, collected in another part of the island, which supplied details for both host and rust, and the long search for definite knowledge of this curious rust and its obscure host was successfully ended. The result shows that the rust is curious, as stated by Montagne, that it is worthy of being placed in a separate genus related to *Puccinia*, *Phragmidium*, and *Uropyxis*, as believed by M. Hariot. Finally, another species of host for it was discovered by the junior author (1912), within the same limited region, and later by Whetzel and Olive (1916) in Porto Rico.

29. PROSPODIUM AMPHILOPHII (Diet. & Holw.) Arth. Jour. Myc. 13: 31. 1907.

Puccinia Amphilophii Diet. & Holw. Bot. Gaz. **24**: 30. 1897.

ON BIGNONIACEAE:

Pithecoctenium echinatum (Aubl.) K. Schum., Caleta Cocodrilos, Isle of Pines, March 8, 1916, II, III, *Britton, Wilson & León 15274*.

This long-cycle rust has heretofore been known only from Mexico.

30. PROSPODIUM LIPPIAE (Speg.) Arth. N. Am. Flora **7**: 161. 1912.

Puccinia Lippiae Speg. Anal. Mus. Nac. Buenos Aires **6**: 224. 1898.

ON VERBENACEAE:

Lippia dulcis Trev., Cacocum (Prov. Oriente), April 6, 1916, II, *Johnston 550*.

The species has not before been reported from the West Indies. It is known from Mexico, Central America, and South America.

The urediniospores are somewhat smaller than those of other collections examined, with pores less evident, but other characters of spores and sori, even to the inconspicuous paraphyses, are the same.

31. PROSPODIUM TUBERCULATUM (Speg.) Arth. N. Am. Flora **7**: 161. 1912.

Puccinia tuberculata Speg. Anal. Soc. Ci. Argent. **10**: 6. 1880.

ON VERBENACEAE:

Lantana involucrata L., Santiago de las Vegas, June 4, 1916, II, iii, *Johnston 770*.

This long-cycle rust has heretofore been known only from Mexico.

32. NEPHLYCTIS TRANSFORMANS (Ellis & Ev.) Arth. Jour. Myc. 13: 32. 1907.

Puccinia transformans Ellis & Ev. Erythea **5**: 6. 1897.

Puccinia exitiosa Syd. & Holw.; Sydow, Monog. Ured. **1**: 245. 1902.

ON BIGNONIACEAE:

Stenolobium stans (L.) D. Don (*Tecoma stans* Juss.), Havana, March 24, 1903, *Holway;* Santiago de las Vegas, May 3, 1905, *Horne*, Feb. 28, 1916, II, III, *Johnston 469;* Cojimar (Prov. Habana), May, 1905, *Baker 2605;* Villa Real near Guanabacoa (Prov. Habana), May 20, 1912, *Bro. León 2943;* Cienfuegos (Prov. Santa Clara), Nov. 3, 1915, II, *Johnston 219;* San Antonio de los Baños (Prov. Habana), June 11, 1916, *Johnston 781.*

The species is a short-cycle rust possessing pycnia and telia, as proven by cultures (Arthur, Jour. Myc. **12**: 22. 1906; **13**: 198. 1907), made in 1905 and 1906. The teliospores for the cultures came from the material sent by Mr. Horne, as listed above. The plants were from seed received from the Bahama islands and sown in the greenhouse the year previous. The greenhouse plants thus infected continued to produce the rust from the same galls for a number of years, under greenhouse conditions. Material fixed from the cultures was utilized by Dr. E. W. Olive in his cytological studies (Sexual cell fusions and vegetative nuclear divisions in the rusts. Ann. Bot. **22**: 331–360. *pl. 22.* 1908). The same author has further studied this material and reported it under the title "The nuclear conditions in certain short-cycled rusts," but only an abstract of the paper (Science II. **33**: 194. 1911) has yet been printed.

The species is known from various parts of Mexico, from New Providence in the Bahama Islands, and from Cuba. *Puccinia elegans* Schröt. of Argentina is a similar short-cycle rust, but with larger and more coarsely sculptured spores, and has not yet been found in North America. Type material for all the names cited has been examined by the senior author. The names and descriptions of the two species involved are unfortunately confused in Sydow's Monographia Uredinearum **1**: 244–245.

33. SPHAEROPHRAGMIUM DALBERGIAE Diet. Hedwigia 32: 30. 1893.

Uredo Sissoo Syd. & Butl. Ann. Myc. 4: 442. 1906.

ON FABACEAE:

Dalbergia Amerimnum Benth., Baracoa (Prov. Oriente), April 14, 1916, II, *Johnston 639.*

The collection shows an abundance of uredinia, but no telia. The characters agree well with the description of the species as given in Sydow, Monog. Ured. 3: 186, but no original specimen has been seen. Although heretofore recognized only from Natal in southern Africa, yet upon comparing the Cuban collection with the one distributed in Sydow, Uredineen *2150*, which was collected by E. J. Butler at Pusa, India, and issued as *Uredo Sissoo*, the agreement seems perfect, and the wide tropical distribution becomes apparent. The description by Dietel in Hedwigia states that the paraphyses are septate, having a cross wall at the middle. That appears to be the case both in the West and East Indian material, but a more critical examination shows that the appearance is due to the arrangement of the cell contents, and not to a cellulose wall. The spores are inclined to be bent to one side, almost kidneyform at times. The two pores of the urediniospores are easily seen.

The *Uredo Dalbergiae* P. Henn., on some species of *Dalbergia* from Brazil, has much smaller, paler and thinner-walled spores. The gross appearance of the sorus is also quite distinct, being smaller and more nearly round.

The reference of this species to the genus *Sphaerophragmium* is based upon the statement by Dietel that he found a single sorus with some half dozen teliospores. The character of the life cycle is problematical.

34. UROMYCES LEPTODERMUS Sydow; Sydow & Butler, Ann. Myc. 4: 430. 1906.

ON POACEAE:

Panicum barbinode Trin., Santiago de Cuba (Prov. Oriente), March 6, 1903, II, *Holway;* Santiago de las Vegas, March 1, 1907, II, III, *Baker* (Barth. Fungi Columb. *2671*), Jan. 29, 1916, II, *Johnston 425;* San Pedro, Isle of Pines, Feb. 12–March 22, 1916, II, *Britton & Wilson 14715, Britton, Britton & Wilson 15357;* Herradura (Prov. Pinar del Rio), March, 1917, II, *Horne.*

The alternate form and host for this heteroecious species are yet unknown. The rust occurs on a number of species of *Panicum* and *Lasiacis* in tropical regions from southern Florida and Mexico into South America, and in the West Indies on the islands of Porto Rico and Jamaica as well as Cuba. It occurs also in India.

35. UROMYCES ERAGROSTIDIS Tracy, Jour. Myc. **7**: 281. 1893.
ON POACEAE:
Eragrostis tephrosanthos Schult., Santiago de las Vegas, June 5, 1916, II, *Johnston 755*.

The species has not before been collected in Cuba, and in the West Indies has been reported only from Bayamon and Rio Piedras in Porto Rico. It is not uncommon in the southern United States, Mexico, and Central America on various species of *Eragrostis*. The aecial form and its host are not known.

36. UROMYCES IGNOBILIS (Sydow) Arth. Mycologia **7**: 181. 1915.
Uredo ignobilis Sydow, Ann. Myc. **4**: 444. 1906.
Uromyces major Arth. Bull. Torrey Club **38**: 377. 1911.
ON POACEAE:
Sporobolus indicus (L.) R. Br., Santiago de las Vegas, June 5, 1916, II, *Johnston 754*.

This is the second collection for the West Indies, the other being from Porto Rico, although it is probably a common tropical rust. It is known also from Mexico and India. Aecia are not known, and telia are not common.

Through the kindness of Mrs. Agnes Chase, material has been examined, taken from the phanerogamic collection of the U. S. Department of Agriculture, as follows, all on *S. indicus:* El Guana, March 24, 1900, II, *404;* Consolación del Sur, April 3, 1900, II, III, *473;* San Diego de los Baños, April 26, 1900, II, *627*, all from Prov. Pinar del Rio, and collected by *Palmer & Riley;* also Isle of Pines, Jan. 31, 1904, II, *A. H. Curtiss 323*.

37. UROMYCES RHYNCOSPORAE Ellis, Jour. Myc. **7**: 274. 1893.
ON CYPERACEAE:
Rynchospora distans (Michx.) Vahl.

The rust was detected on this host in the phanerogamic herbarium at the N. Y. Bot. Garden, on a specimen collected at Pinar del Rio, no date but probably about 1857, *Charles Wright 3399*. This heteroecious rust, whose aecia are unknown, occurs on many species of *Rynchospora* throughout the eastern United States and the West Indies, the record for the islands being Jamaica, Porto Rico, Martinique, Bermuda, and the Bahamas.

38. UROMYCES SCLERIAE P. Henn. Hedwigia Beibl. **38**: 67. 1899.
ON CYPERACEAE:
Scleria lithosperma (L.) Sw.

This heteroecious species was detected in the phanerogamic herbarium of the N. Y. Bot. Garden, on this host, collected six miles from northwestern end Cayo Coco (Prov. Camagüey), Oct. 23–24, 1909, *J. A. Shafer 2729*, showing both uredinia and telia. Previously it has been known in North America only from Porto Rico. The aecial form is yet to be discovered.

39. UROMYCES COMMELINAE (Speg.) Cooke, Trans. Roy. Soc. Edinb. **31**: 342. 1888.
ON COMMELINACEAE:
Commelina longicaulis Jacq., Cienfuegos (Prov. Santa Clara), Nov. 5, 1915, *Johnston 207*.

This species is imperfectly known. Only uredinia have been found in the western hemisphere, but telia have been collected on the African coast of the Red Sea, the adjacent island of Socotra, and the Malabar coast of India. It is assumed, without direct evidence, that the species also includes pycnia and aecia in its life cycle, but whether it is to be considered as autoecious or heteroecious is highly problematical. In America it is recorded also from Jamiaca, Porto Rico, St. Croix, and South America.

The host is usually given as *C. nudiflora* L., a name, as reported at the New York Botanical Garden, belonging to a very different plant, not a member of the true genus *Commelina*.

40. UROMYCES CELOSIAE Diet. & Holw. Bot. Gaz. **31**: 326. 1901.
ON AMARANTHACEAE:
Iresine Celosia L. (I. *paniculata* Poir.), Santiago de las Vegas, Feb. 28, 1916, II, *Johnston 468*.

This is the first record for the West Indies, although known for Mexico and Guatemala. The species is imperfectly understood. Beside uredinia and telia there is a possibility that pycnia and aecia appear to complete the life cycle, and there is some likelihood of heteroecism.

41. UROMYCES JAMAICENSIS Vesterg. Ark. Bot. Stockh. 4^{15}: 33. 1905.

ON FABACEAE:

Bauhinia divaricata L., Caleta Grande, Isle of Pines, March 9, 1916, *Britton, Wilson & León 15335*.

An autoecious species, apparently short-cycled although no pycnia have yet been detected. It occurs in Mexico on the same host, and in Porto Rico and Jamaica on other hosts.

42. UROMYCES MEDICAGINIS Pass.; Thüm. Herb. Myc. Oecon. *156*. 1874.

Uromyces Medicaginis-falcatae Wint. in Rab. Krypt.-Fl. **1**: 159. 1881.

ON FABACEAE:

Medicago sativa L., Santiago de las Vegas, May 13, 1916, II, *Johnston 700*.

The alfalfa rust has not before been reported from Cuba, and only one other West Indian station is known for it, Bermuda. When it does occur the rust appears to attack its host with much virulence, causing the leaves to roll up and shrivel.

The species is considered to be heteroecious, with aecia on upright-growing euphorbias of the genus *Tithymalus*, but no aecia have been found in America, and no cultures have been made with American material.

43. UROMYCES NEUROCARPI Dietel, Hedwigia **34**: 292. 1895.

Uromyces insularis Arth. Bull. Torrey Club **33**: 515. 1906.

ON FABACEAE:

Clitoria rubiginosa Juss., Baracoa (Prov. Oriente), March, 1903, II, III, *Underwood & Earle 1386*, April 14, 1916, II, *Johnston 615;* Rio de la Casas, Isle of Pines, March 20, 1916, II, III, *Britton & Wilson 15653;* Sabanilla (Prov. Oriente), April 22, 1916, II, *Johnston 631*.

This species was detected also in the phanerogamic herbarium of the N. Y. Bot. Garden on the same host from Tabajó at base of El Yunque, Dec. 12, 1910, *J. A. Shafer 7719*. The species has been taken also in Porto Rico and Jamaica, but outside of the West Indies only in Vera Cruz, Mexico, and Brazil. The species is doubtless autoecious, requiring pycnia and aecia to complete the life cycle, although they have not yet been discovered.

44. UROMYCES APPENDICULATUS (Pers.) Fries, Summa Veg. Scand. 514. 1849.

ON FABACEAE:

Phaseolus vulgaris L., Havana, March 21, 1903, II, iii, *Holway;* Candelaria (Prov. Pinar del Rio), Feb. 17, 1917, II, *Johnston 938.*

Vigna vexillata (L.) A. Rich., Toa, Baracoa (Prov. Oriente), April 17, 1916, II, *Johnston 568.*

The species has been detected also on phanerogamic specimens in the herbarium of the N. Y. Bot. Garden, on *Dolichos Lablab* L. (*Lablab vulgaris* Savi) from Regla (Prov. Habana), April 8, 1903, II, *J. A. Shafer 98;* on *Vigna repens* (L.) Kuntze, Punta de Afuera, Bahia Honda (Prov. Pinar del Rio), Dec. 14, 1910, II, *Percy Wilson 9261; Vigna vexillata* (L.) A. Rich., Campo Florido (Prov. Habana), July 18, 1912, II, *Bro. León 3352.*

The collection on *Vigna vexillata*, made by Mr. Johnston, shows urediniospores with two or three pores, varying from equatorial to markedly superequatorial, a condition also noted in the Porto Rican rusts on this host genus (Mycologia **7**: 185. 1915).

The species is autoecious, but pycnia and aecia have not been reported from the tropics, and even telia are somewhat rare. The rust is cosmopolitan on *Dolichos, Phaseolus, Strophostyles, Vigna,* and probably other genera.

45. UROMYCES DOLICHOLI Arth. Bull. Torrey Club **33**: 27. 1906.

ON FABACEAE:

Cajan Cajan (L.) Millsp. (*Cajanus indicus* Spreng.), Santiago de las Vegas, Jan. 30, 1916, II, *Johnston 461.*

Although no pycnia or aecia have been found, yet the affinities of this rust lead one to believe that it is autoecious. It ranges from Texas to Colombia and probably to Argentina, the collections usually showing only uredinia. Various notes regarding the species are given in the Uredinales of Porto Rico (Mycologia **7**: 186–188. 1915). Other West Indian islands represented are Porto Rico and St. Domingo.

46. UROMYCES HEDYSARI-PANICULATI (Schw.) Farl.; Ellis, N. Am. Fungi *246.* 1879.

Uromyces solidus Berk. & Curt. Grevillea **3**: 57. 1874.

Uredo Desmodii-tortuosi P. Henn. Hedwigia **35**: 252. 1896.

ON FABACEAE:

Meibomia Scorpiurus (Sw.) Kuntze (*Desmodium Scorpiurus* Desv.), Soledad, Cienfuegos (Prov. Santa Clara), Nov. 5, 1915, II, *Johnston 194;* Matanzas (Prov. Matanzas), Feb. 7, 9, 1916, II, *Britton, Britton & Wilson 14087;* Rio de las Casas, Isle of Pines, March 20, 1916, II, *Britton & Wilson 15652;* Santiago de las Vegas, Jan. 30, 1916, II, *Johnston 460;* Omaja (Prov. Oriente), March 31, 1916, II, *Johnston 599.*

Meibomia tortuosum (Sw.) Kuntze (*Desmodium tortuosum* DC.), Santiago de las Vegas, Feb. 26, 1916, II, *Johnston 149.*

The rust is probably not rare throughout the island in the uredinial stage. It has been detected in the phanerogamic herbarium of the N. Y. Bot. Garden on *Meibomia Scorpiurus,* Rio San Miguel (Prov. Pinar del Rio), Dec. 17, 1910, *Percy Wilson 9380,* and on *M. tortuosum* near Vento (Prov. Habana), Aug. 13, 1907, *Baker, Tracy & Hasselbring 3079,* and near Herradura (Prov. Pinar del Rio), Aug. 28–31, 1910, *Britton & Earle 6591.*

Through the kindness of Dr. Lindau of the Berlin Museum, the senior author has recently been enabled to examine the spores from the collection made by Sintenis in Porto Rico, named by Hennings *Uredo Desmodii-tortuosi,* and finds that they are finely echinulate, and not truly smooth as described by Hennings, and in every way agree with those of the common form.

The species is only known elsewhere in the West Indies from Porto Rico, but has a continental range both north and south. It is autoecious, but pycnia and aecia are rarely seen, the latter being pale and inconspicuous.

47. UROMYCES JANIPHAE (Wint.) Arth. Mycologia **7**: 190. 1915.

ON EUPHORBIACEAE:

Manihot Manihot (L.) Cockerell (*M. utilissima* Pohl, *Jatropha Manihot* L.), Santiago de las Vegas, Feb. 4, 1916, II, *Johnston;* same, Oct. 13, 1916, *Johnston 903.*

The material collected by Mr. Johnston affected the fruit with a strong development of uredinia; all other material seen has been on the leaves or stems of the plant.

The species is autoecious, with all spore forms, and is known from Porto Rico, Mexico, and South America. Aecia and telia have been found only in Mexico.

48. UROMYCES PROËMINENS (DC.) Pass. Rab. Fungi Eur. *1795*. 1873.

Uromyces Euphorbiae Cooke & Peck; Peck, Ann. Rep. N. Y. State Mus. **25**: 90. 1873.

ON EUPHORBIACEAE:

Chamaesyce hirta (L.) Millsp. (*Euphorbia hirta* L., *E. pilulifera* L.), Soledad, Cienfuegos (Prov. Santa Clara), Nov. 4, 1915, II, *Johnston 223;* Herradura (Prov. Pinar del Rio), March, 1917, I, II, *Horne.*

Chamaesyce hypericifolia (L.) Small (*Euphorbia hypericifolia* L.), Madruga (Prov. Habana), Aug. 14, 1916, II, III, *Johnston 871.*

Poinsettia heterophylla (L.) Kl. & Garcke (*Euphorbia heterophylla* L.), Santiago de las Vegas, May 19, 1905, II, *Horne,* Feb. 26, 1916, II, *Johnston 487;* Saetia (Prov. Oriente), April 8, 1916, II, III, *Johnston 546.*

This autoecious species possessing pycnia, aecia, uredinia, and telia is probably rather common throughout the West Indies, as well as northward and southward. It has been reported from Jamaica, Porto Rico, St. Croix, and the Bahamas. The aecia, which are not uncommon, usually occupy the under surface of all the leaves of erect and somewhat drawn and etiolated shoots. The uredinia of Charles Wright's collection no. 720, reported in the Cuban Fungi under the name *Trichobasis euphorbiaecola* B. & C., appear to be on *Chamaesyce hirta,* judging from the hairs and serration of the fragment of leaf seen from the Herb. Curtis, kindly transmitted by Dr. W. G. Farlow.

49. **Uromyces Cupaniae** (Speg.) nom. nov.

Uredo cristata Speg. Anal. Soc. Ci. Argent. **17**: 119. 1884.

ON SAPINDACEAE:

Cupania macrophylla A. Rich., Santiago de las Vegas, June 6, 1905, *Baker 88,* Dec. 3, 1916, *Johnston 927;* San Antonio de las Baños (Prov. Habana), June 11, 1916, *Johnston 779;* Taco Taco (Prov. Pinar del Rio), Sept. 17, 1916, *Johnston 876.*

Pycnia amphigenous, thickly scattered among the telia over dark-colored, hypertrophied and bullate areas 2–8 mm. across, noticeable, subepidermal, dark brown, globoid or flattened-globose in section, 80–130 μ in diameter by 65–125 μ in height; ostiolar filaments compact, 30–40 μ long.

Telia amphigenous, scattered over dark-colored, bullate areas, 2–8 mm. across, strongly punctiform, main part of the sorus very deep-seated within the mesophyll, opening by a pore; paraphyses and peridium none; teliospores obovate or fusiform, 16–29 by 40–58 μ, narrowed below, rounded or somewhat narrowed above; wall colorless or nearly so, the inner portion firm, 1–2 μ thick, the outer portion hygroscopic, swelling to 5–15 μ thick, strongly tuberculate along prominent ridges or wings, especially toward the summit; pedicel completely fugacious.

This rust is most unusual in gross appearance. The swollen areas are prominent, both from the chocolate-brown color and from being well raised above the leaf surface. The teliospores are ejected from the narrow openings of the sori in colorless masses. In vertical section the sori are found to be flask-shaped, with two or more layers of host cells above them, and having the spores developed from a hymenium at the base. The crested appearance of the teliospores is highly distinctive.

The specimens collected by Baker in 1905 were on old and bleached leaves, and had little appearance of a rust. A packet in the Arthur herbarium had been labelled *Gymnosporangium guaraniticum*, a synonym for a Hyphomycetous fungus now called *Patouillardiella guaranitica*. The identity of the fungus was not ascertained, although much study was given to it, until the excellent material from the junior author was available. The characters of the rust were then easily obtained, and soon identified with those of *Uredo cristata* Speg., a species founded on an unidentified species of Sapindaceae, collected by B. Balansa in Paraguay, January, 1882, no. *3474*. A new specific name is now given, as the one applied by Spegazzini is already in use in the genus *Uromyces*.

In his comments Spegazzini calls it "species pulcherrima distinctissima," which it truly is. It is a short-cycled rust, so very distinctive that it is impossible to state its systematic position. Although described as a *Uromyces*, yet it has affinities with both the *Uropyxidatae* and *Phragmidiatae*. There is considerable similarity to the telia of *Skierka*, and it may represent a correlated short-cycle genus. Until the spores are germinated, it can not be known whether the pores are apical or lateral, a character having considerable importance.

50. UROMYCES HOWEI Peck, Ann. Rep. N. Y. State Mus. **30**: 75. 1879.

ON ASCLEPIADACEAE:

Asclepias curassavica L., Santiago de las Vegas, Oct. 24, 1915, II, *Johnston 132;* San Pedro, Isle of Pines, Feb. 12–March 22, 1916, II, III, *Britton & Wilson 14809;* Baracoa (Prov. Oriente), April 15, 1916, II, *Johnston 519.*

Asclepias nivea L., San Antonio de los Baños (Prov. Habana), June 11, 1916, II, *Johnston 778.*

The species is common in temperate regions northward, but rare in the tropics. The only other West Indian island where it has been taken is Porto Rico.

The life cycle is uncertain. Only uredinia and telia are known, and whether the rust possesses both pycnia and aecia, and whether it is autoecious or heteroecious, are yet wholly open questions.

51. UROMYCES GEMMATUS Berk. & Curt.; Berkeley, Jour. Linn. Soc. **10**: 357. 1869.

ON CONVOLVULACEAE:

Jacquemontia nodiflora (Desv.) G. Don (*Convolvulus nodiflorus* Desv.), Prov. Oriente, 1856, II, *Charles Wright.*

The species is autoecious, having pycnia, uredinia, and telia, but no aecia. The collection made by Charles Wright, here listed, is in the Curtis collection at Harvard University. It is labelled "*Uredo gemmata* Berk. & Curt. var.," and possesses only uredinia. The type of the species in the Kew herbarium, Wright's no. 278, has not been seen. The species was not again collected until found by F. L. Stevens in a number of localities in Porto Rico, 1913. Specimens, now first reported, were secured by E. W. D. Holway in Porto Rico in 1911, and in Jamaica in 1915. The only other known locality is St. Croix. A full description of the species with notes is given in Mycologia **7**: 192–193. 1915.

52. UROMYCES DOLICHOSPORUS Diet. & Holw. Bot. Gaz. **31**: 327. 1901.

ON BORAGINACEAE:

Tournefortia volubilis L., Punta Sabanilla, Cienfuegos Bay (Prov. Santa Clara), Feb. 24, 1910, II, *Britton, Earle & Wilson 4575*.

The species is autoecious, having large subepidermal pycnia, chestnut-brown uredinia, and colorless telia. The fungus distorts and etiolates young and growing organs. It is known elsewhere only from Oaxaca, Mexico.

53. UROMYCES HELLERIANUS Arth. Bull. Torrey Club **31**: 2. 1904.

ON CUCURBITACEAE:

Cayaponia racemosa (Sw.) Cogn., Soledad, Cienfuegos (Prov. Santa Clara), Nov. 6, 1915, *Johnston 192*.

Melothria guadalupensis (Spreng.) Cogn., Riverside (Prov. Camagüey), Nov. 30, 1915, *Johnston 285*.

Uredinia and a few telia were detected also on a phanerogamic specimen in the herbarium of the N. Y. Bot. Garden, on *Melothria guadalupensis*, from Buenaventura (Prov. Pinar del Rio), Dec. 13, 1910, *Percy Wilson 9237*. The species occurs in Porto Rico and Guatemala. It is considered autoecious and to have pycnia and aecia, which are yet undetected, however.

54. UROMYCES BIDENTICOLA (P. Henn.) Arth. Mycologia **9**: 71. 1917.

Klebahnia Bidentis Arth. Mycologia **7**: 196. 1915.

ON CARDUACEAE:

Bidens leucantha Willd., Santiago de las Vegas, March 11, 1916, *Johnston 729;* Baracoa (Prov. Oriente), April 17, 1916, II, III, *Johnston 569;* Holguin (Prov. Oriente), April 4, 1916, II, *Johnston 577;* Paso Estancia (Prov. Oriente), May 3, 1916, II, *Johnston 702;* San Antonio de los Baños (Prov. Habana), June 11, 1916, II, III, *Johnston 765*.

Bidens pilosa L., Havana, Feb. 5, 1916, II, *Britton, Britton & Wilson 14138;* Caleta Cocodrilos, Isle of Pines, March 8, 1916, II, *Britton, Britton & Wilson 15268*.

This autoecious species, having pycnia, uredinia, and telia, is now first reported from Cuba, but has been known from Porto Rico, Jamaica, and Martinique, as well as from the continents of North and South America. It has usually been listed under *U. Bidentis* Lagerh., a name belonging to a similar short-cycle species on the same hosts, not yet reported for Cuba.

55. UROMYCES COLUMBIANUS Mayor, Mém. Soc. Neuch. Sci. Nat. 5: 467. 1913.

Nigredo columbiana Arth. Mycologia 7: 194. 1915.

ON CARDUACEAE:

Melanthera brevifolia O. E. Schultz, Santiago de las Vegas, July 26, 1915, II, III, *Johnston 143*.

Uredinia have been found on phanerogamic specimens in the herbarium of the N. Y. Bot. Garden, on *M. brevifolia*, Vedado (Prov. Habana), May, 1909, *Bro. León 1371*, and on *M. hastata cubensis* O. E. Schultz, near Sta. Fé (Prov. Habana), Oct. 7, 1915, *Bro. León*.

This autoecious rust has heretofore been known only from Porto Rico, and from the type locality in Colombia, S. A. The life cycle embraces pycnia, aecia, uredinia, and telia.

56. PUCCINIA PURPUREA Cooke, Grevillea 5: 15. 1876.

ON POACEAE:

Holcus halepensis L. (*Sorghum halepense* Pers., *Andropogon halepensis* Brot.), Santa Clara (Prov. Santa Clara), March 19, 1903, II, *Holway* (Barth. Fungi Columb. *4670*); Havana, March 21, 1903, II, *Holway* (Barth. N. Am. Ured. *963*) and March 24, 1903, *Holway;* Aguacate (Prov. Habana), March 23, 1903, *Holway;* Santiago de las Vegas, July 19, 1904, *Horne*, and Sept. 27, 1915, *Johnston 169;* Herradura (Prov. Pinar del Rio), March, 1917, II, III, *Horne*.

Holcus Sorghum L. (*Sorghum vulgare* Pers.), Santiago de las Vegas, Nov. 17, 1905 (Broom, Kaffir, and Milo), *Horne*, March 1, 1907, *Baker 1716, 1717* (Barth. N. Am. Ured. *1072*, Fungi Columb. *2464*, Sydow Ured. *2328*), March 10, 1916 (Egyptian millet), *Johnston 730*.

The species is undoubtedly heteroecious, but the aecial host is yet undiscovered. A very common rust in warm regions, usually producing both uredinia and telia. The other West Indian islands represented are Jamaica, Porto Rico, and Bermuda.

57. PUCCINIA CENCHRI Diet. & Holw. Bot. Gaz. **24**: 28. 1897.

ON POACEAE:

Cenchrus echinatus L., Santiago de Cuba (Prov. Oriente), March 7, 1903, II, *Holway;* Itabo (Prov. Matanzas), Nov. 12, 1915, II, *Johnston 181;* Baracoa (Prov. Oriente), April 18, 1916, II, *Johnston 664;* Santiago de las Vegas, June 5, 1916, II, III, *Johnston 764.*

Cenchrus viridis Spr., Santiago de las Vegas, Sept. 27, 1915, II, *Johnston 165;* Saetia (Prov. Oriente), April 8, 1916, ii, *Johnston 537.*

A heteroecious species whose alternate host is not known. It occurs in the southern United States, Mexico, Porto Rico, and the Bahamas.

58. PUCCINIA DEFORMATA Berk. & Curt. Jour. Linn. Soc. **10**: 357. 1869.

ON POACEAE:

Olyra latifolia L., without locality, January, 1857, II, III, *Charles Wright 596;* Soledad, Cienfuegos (Prov. Santa Clara), Nov. 7, 1915, II, *Johnston 247;* Ceballos (Prov. Camagüey), March 24, 1916, II, *Johnston 509.*

The type collection was made by Charles Wright in eastern Cuba, January, 1857, locality not given. A number of collections have been made in Porto Rico, and one in Nicaragua. The species is considered autoecious, but no clue to the alternate host has yet been obtained.

59. PUCCINIA HUBERI P. Henn. Hedwigia Beibl. **39**: 76. 1900.

ON POACEAE:

Panicum fasciculatum Sw., Toa, Baracoa (Prov. Oriente), April 17, 1916, II, *Johnston 641.*

Paspalum virgatum L., Ceballos (Prov. Camagüey), Nov. 23, 1915, II, III, *Johnston 307.*

This imperfectly known, heteroecious species has been reported from Porto Rico on *Panicum fasciculatum* and *P. trichoides*, but not from other West Indian islands. It was first described from Brazil.

60. PUCCINIA SUBSTRIATA Ellis & Barth. Erythea 5: 47. 1897.

Puccinia Chaetochloae Arth. Bull. Torrey Club 34: 585. 1907.

ON POACEAE:

Chaetochloa geniculata (Lam.) Millsp. & Chase (*C. imberbis* Scribn., *C. purpurascens* S. & M.), Santiago de las Vegas, Feb. 26, 1916, II, *Johnston 483;* same, June 5, 1916, II, *Johnston 762;* San Pedro, Isle of Pines, Feb. 12–Mar. 22, 1916, II, *Britton & Wilson 15439;* Baracoa (Prov. Oriente), April 17, 1916, II, *Johnston 558.*

Chaetochloa onurus (Willd.) S. & M., Ceballos (Prov. Camagüey), Nov. 25, 1915, II, *Johnston 301.*

Chaetochloa verticillata (L.) Scribn., Botanic Garden, Havana, March 21, 1903, *Holway.*

Syntherisma sanguinalis (L.) Dulac (*Panicum sanguinale* L.), Santiago de las Vegas, Feb. 26, 1916, *Johnston 482.*

This heteroecious species, with the alternate host unknown, is a common cosmopolitan rust occurring on many species of hosts, especially in warmer regions. It ranges from Nebraska southward into South America. Of the other West Indian islands it is known from Jamaica, Porto Rico, and Bermuda.

In addition to the above localities, a number have been found in connection with phanerogamic specimens in the herbarium of the N. Y. Bot. Garden: on *C. geniculata,* Isle of Pines, May, 1910, II, *O. E. Jennings 154;* Los Palacios (Prov. Pinar del Rio), Jan. 15, 1912, II, *J. A. Shafer 11795;* on *C. onurus* (Willd.) S. & M., near the mouth of Bueyvaca (Prov. Matanzas), Aug. 28, 1903, II, *Britton & Wilson 29;* near Santiago, Sept. 6, 1906, II, *Norman Taylor 232;* Sierra Nipe (Prov. Oriente), Dec. 5, 1909, *J. A. Shafer 3020;* on *C. setosa* (Sw.) Scribn. (*Setaria setosa* Beauv.), El Yumuri (Prov. Matanzas), April, 1849, *Rugel 880.*

61. **Puccinia Anthephorae** (Syd.) comb. nov.

Uredo Anthephorae Sydow, Ann. Myc. 1: 22. 1903.

ON POACEAE:

Anthephora hermaphrodita (L.) Kuntze (*A. elegans* Schreb.).

Through the kindness of Dr. H. Sydow, some of the original collection of this species has been examined. It differs from the uredinia of *Puccinia Chaseana* Arth., occurring on the same host, in having thick-walled urediniospores. The collection, as stated by the Sydows (l.c.), was made in Cuba by Ramon de la Sagra. No date or locality is given.

Telia were found associated with uredinia on a phanerogamic specimen of the same host, at the New York Botanical Garden, collected between Portland Point and Rocky Point, Jamaica, March 5, 1908, *N. L. Britton 1917*. A few teliospores were found on another similar phanerogamic specimen in the same herbarium, collected in St. Croix, Feb. 6, 1896, *Alfred E. Ricksecker 253*. From these two collections the following characters for the telia have been secured.

Telia amphigenous, scattered, linear or oblong, 0.2–2 mm. long, early naked, opening by a longitudinal slit of the epidermis, compact, blackish-brown, ruptured epidermis noticeable; teliospores broadly ellipsoid, 23–26 by 31–35 μ, rounded at both ends, only slightly constricted at septum; wall chestnut-brown, 3–4 μ thick, somewhat thicker above, 5–7 μ, with a broad, low, concolorous umbo, smooth; pedicel hyaline, 9 μ broad, not tapering, up to 85 μ long, the wall thin, 1 μ.

The species is only known from the three collections cited, but is doubtless widespread, although it may not be abundant, throughout the West Indies, as the host is a wayside weed.

62. PUCCINIA RHAMNI (Pers.) Wettst. Verhl. Zool.-Bot. Ges. Wien **35**: 545. 1886.

Puccinia coronata Corda, Icones **1**: 6. 1837.

ON POACEAE:

Avena sativa L., Santiago de las Vegas, March 14, 1917, II, III, *Johnston 937*.

This is the only record of the oat rust for the West Indies. The species is represented in Mexico by two collections on *Bromus* from the federal district made by E. W. D. Holway, and is not reported from Central America.

63. PUCCINIA POCULIFORMIS (Jacq.) Wettst. Verhl. Zool.-Bot. Ges. Wien **35**: 544. 1886.

Puccinia graminis Pers. Neues Mag. Bot. **1**: 119. 1794.

ON POACEAE:

Triticum vulgare Vill. (*T. sativum* Lam.), without locality or date (*Ramon de la Sagra*?).

The only record of the black stem-rust of wheat for any of the West Indian islands is in the Flora Cubana (Montagne, Pl. Cell.

Cuba 293. 1842), where the species is described in full and the statement is made that it occurs on culms, leaves, and glumes, and even awns, of wheat. The record is presumably based on a collection by Ramon de la Sagra.

64. PUCCINIA SORGHI Schw. Trans. Am. Phil. Soc. II. **4**: 295. 1832.

ON POACEAE:

Zea Mays L., Santiago de las Vegas, Aug. 26, 1904, *Baker 1265*, Aug. 4, 1905, *Horne*, Oct. 1, 1915, *Johnston 171;* Guanajay (Prov. Pinar del Rio), Jan. 27, 1915, II, *Johnston 142;* Artemisa (Prov. Pinar del Rio), Jan. 29, 1915, II, III, *Johnston 148.*

The rust is heteroecious, with aecia on various species of *Oxalis*. The rust is rarely collected in tropical regions, this being the only record for the West Indies.

65. PUCCINIA CANALICULATA (Schw.) Lagerh. Tromsö Mus. Aarsh. **17**: 51. 1894.

Puccinia Cyperi Arth. Bot. Gaz. **16**: 266. 1891.

ON CYPERACEAE:

Cyperus ferax L. C. Rich., El Yunque, Baracoa (Prov. Oriente), March 10, 1903, II, III, *Holway;* Baracoa (Prov. Oriente), April 15, 1916, II, *Johnston 632.*

Cyperus sp., Herradura (Prov. Pinar del Rio), Jan. 1917, II, III, *Horne.*

A cosmopolitan, heteroecious rust, common on many species of *Cyperus* and *Kyllinga*. It has been proven by cultures to possess aecia on *Xanthium* and *Ambrosia* in the northern United States, but it doubtless has other aecial hosts. Of the other West Indian islands it is known from Jamaica, Porto Rico, and Martinique.

The collection from Herradura has most of the urediniospores with three pores, instead of the usual 2-pored condition with occasionally three pores.

66. PUCCINIA ELEOCHARIDIS Arth. Bull. Iowa State Coll. 156. 1884.

ON CYPERACEAE:

Eleocharis geniculata (L.) R. Br., Baracoa (Prov. Oriente), April 15, 1916, II, *Johnston 501.*

The uredinia were also found on *E. capitata* (L.) R. Br. (*Scirpus capitatus* L.), collected by Charles Wright in Cuba, locality and date not given, the specimen being in the phanerogamic herbarium of Purdue University at Lafayette, Ind., having been received from G. W. Clinton.

The species is heteroecious, it having been shown by culture that the aecia occur on *Eupatorium*. In the tropics the uredinial stage is the one usually collected, and it may be that the rust is there propagated solely by the repeating spores.

Porto Rico is the only other West Indian island from which it is reported.

67. PUCCINIA SCLERIICOLA Arth. Mycologia **7**: 232. 1915.

ON CYPERACEAE:

Scleria verticillata Muhl.

This heteroecious species, whose aecia are unknown, occurs on a number of species of hosts from Florida and Georgia. The record for Cuba is based upon a phanerogamic collection in the herbarium of the N. Y. Bot. Garden, from Nuevo Gerona, Isle of Pines, December, 1903, *A. H. Curtiss.*

68. PUCCINIA FUIRENAE Cooke, Grevillea **6**: 137. 1878.

ON CYPERACEAE:

Fuirena simplex Vahl.

This heteroecious species, whose aecia are unknown, was detected in its uredinial stage on a phanerogamic collection in the National Herbarium and communicated by Mrs. Agnes Chase. It was collected near Nueva Gerona, Isle of Pines, Dec. 17, 1903, by *A. H. Curtiss 237.* The species has been known from South Carolina, Florida, Alabama, and Texas, and is now first reported for the West Indies.

69. PUCCINIA SCIRPI DC. Fl. Fr. **2**: 223. 1805.

Aecidium Nymphoidis DC. Fl. Fr. **2**: 597. 1805.

ON MENYANTHACEAE:

Limnanthemum Grayanum Griseb., Pinar del Rio, December, 1858, O, I, *Charles Wright 929.*

This heteroecious species is represented in America by only two collections. The uredinia were detected in 1902 on *Scirpus lacustris* L. from Guanica, Porto Rico, *A. A. Heller 6291.* The aecia, as listed above, have been examined in a collection in the herbarium of Dr. W. G. Farlow at Cambridge, Mass., and are characteristic of the species in both gross and microscopic characters. They are accompanied by pycnia. The packet is marked 1857–8, but the year is undoubtedly 1858, as Wright was in Cuba December, 1858, but not there in December, 1857 (cf. Underwood, Wright's explorations in Cuba, Bull. Torrey Club **32**: 293. 1905). This is the only collection on this host genus yet made in America.

70. PUCCINIA SMILACIS Schw. Nat. Ges. Leipzig **1**: 72. 1822.

ON SMILACEAE:

Smilax havanensis Jacq., San Antonio de los Baños (Prov. Habana), June 11, 1916, II, *Johnston 783*.

A seemingly rare rust in the West Indies, having been collected only once before, in Porto Rico.

71. PUCCINIA CANNAE (Wint.) P. Henn. Hedwigia **41**: 105. 1902.

ON CANNACEAE:

Canna indica L., Santiago de las Vegas, July 2, 1906, *Baker* (Barth. Fungi Columb. *2387*, Sydow Ured. *2114*), July 10, 1906, *Cook;* Los Indios, Isle of Pines, Feb. 13, 1916, II, *Britton, Britton & Wilson 15350;* Baracoa (Prov. Oriente), April 18, 1916, II, *Johnston 662*.

Canna sp., Soledad, Cienfuegos (Prov. Santa Clara), Nov. 4, 1915, *Johnston 220*.

Only uredinia and telia are known for the species, and the character of the remaining part of the life cycle can not be predicted. It is also reported from Jamaica and Porto Rico.

72. PUCCINIA POLYGONI-AMPHIBII Pers. Syn. Fung. 227. 1801.

ON POLYGONACEAE:

Persicaria punctata (Ell.) Small (*Polygonum punctatum* Ell., *P. acre* H.B.K.), Paso Estancia (Prov. Oriente), May 2, 1916, II, *Johnston 517;* San Antonio de los Baños (Prov. Habana), June 11, 1916, II, *Johnston 777*.

These collections show an abundance of uredinia, but no telia, being the usual condition on this host. The first record for the West Indies was from Haiti in 1910, and it was lately taken in Porto Rico. It is a common rust in temperate regions both north and south, as well as in the Old World. Cultures have been conducted both in America and Europe, showing the aecia to occur on species of *Geranium*.

73. **Puccinia striolata** (Speg.) comb. nov.

Uredo striolata Speg. An. Soc. Ci. Arg. **9**: 173. 1880.

Puccinia macropoda Speg. An. Soc. Ci. Arg. **10**: 8. 1880.

ON AMARANTHACEAE:

Iresine angustifolia Euphr. (*I. elatior* Rich.), Cacocum (Prov. Oriente), April 6, 1916, II, *Johnston 534*.

Iresine Celosia L. (*I. paniculata* Kuntze), Aguacate (Prov. Habana), March 23, 1903, *Holway*.

This rust is probably autoecious, but the life cycle is not fully known. No pycnia or aecia have yet been found. Only one collection made by Spegazzini in April, 1880, at Chacarita, Argentina, on *Iresine Celosia* L. (*I. celosioides* L.), is so far known bearing telia. All other collections bear only uredinia.

The species has also been reported from the islands of St. Thomas and Porto Rico, and from Ecuador and Argentina.

74. PUCCINIA RIVINAE (Berk. & Curt.) Speg. An. Mus. Buenos Aires **19**: 304. 1909.

Aecidium Rivinae Berk. & Curt. Jour. Lin. Soc. **10**: 358. 1869.

Endophyllum Rivinae Arth. N. Am. Flora **7**: 126. 1907.

Puccinia Raunkiaerii Ferd. & Winge, Bot. Tiddskr. **29**: 8. 1908.

ON PETIVERIACEAE (PHYTOLACCACEAE):

Rivina humilis L., Managua near Havana, June 11, 1906, *Cook;* Sabanilla (Prov. Oriente), April 22, 1916, *Johnston 516*.

Rivina octandra L., San Antonio de los Baños (Prov. Habana), April 5, 1905, *Baker & Van Hermann 4775;* Cacocum (Prov. Oriente), April 6, 1916, *Johnston 515;* Santiago de las Vegas, Feb. 27, 1916, *Johnston 477*, May 28, 1916, I, *Johnston 760*, June 4, 1916, II, *Johnston 771;* Paso Estancia (Prov. Oriente), May 3, 1916, I, *Johnston 689, 705;* Ceballos (Prov. Camagüey), March 24, 1916, I, *Johnston 511;* Antilla (Prov. Oriente), April 8, 1916, II, III, *Johnston 512*.

An autoecious species with all spore forms, occurring also in Porto Rico and St. Thomas. The rust greatly distorts the young shoots, as shown in the cut (p. 97). Germination of the aeciospores was first undertaken by the junior author in March, 1916, by sowing them on the surface of hardened beef agar in a Petri dish. Spores from the small groups of aecia on the leaves germinated readily over night, producing long hyphal tubes, characteristic of aeciospores. The spores from aecia on the greatly hypertrophied shoots, however, could not be made to germinate. Repeated attempts again in 1917 resulted in the same way. Specimens were sent to Lafayette, Ind., which gave no better results. A collection on hypertrophied shoots, made at Santiago de las Vegas on June 14, 1917, and received in Lafayette one week later and quite dry, was sown on the surface of water. The next day, June 22, long unseptated and unbranched germ tubes appeared sparingly. It is proven, therefore, that the hypertrophied form, long known as *Endophyllum Rivinae*, is an aecial form belonging to *Puccinia Rivinae.*

75. PUCCINIA ZORNIAE (Diet.) McAlpine, Rusts of Australia 172. 1906.

Uredo Zorniae Diet. Hedwigia **38**: 257. 1899.

ON FABACEAE:

Zornia diphylla (L.) Pers., Herradura (Prov. Pinar del Rio), Sept. 30, 1904, II, III, *Baker 2143*.

This imperfectly known rust, usually collected in the uredinial form, occurs also in Florida and Mississippi, as well as in Africa and Australia. This is the first record for the West Indies. Heretofore teliospores have been reported from Australia only, but both of the collections here listed show telia interspersed with the uredinia. The telia are small and inconspicuous, and were first found when sectioning to ascertain if pycnia might be present. Some of the sori contained only teliospores, no urediniospores being intermixed. The spores are somewhat more slender than those described by McAlpine, and seemingly paler. They appear to be capable of germination upon maturity.

The rust was detected also by Mr. Percy Wilson in the phanerogamic herbarium of the N. Y. Bot. Garden, on the same host, collected at Pinar del Rio, April 23, 1903, *J. A. Shafer 292*.

76. PUCCINIA INFLATA Arth. Bull. Torrey Club **33**: 516. 1906.

ON MALPIGHIACEAE:

Stigmaphyllon periplocifolium (Desf.) Juss., Baracoa (Prov. Oriente), March 13, 1903, II, III, *Holway* (Barth. N. Am.

Ured. *42*); near Cayamas (Prov. Santa Clara), Oct. 13, 1904, II, *Baker 3538*.

Stigmaphyllon Sagraeanum A. Juss. (*S. reticulatum* A. Juss.), Rio San Juan (Prov. Santa Clara), March 24–25, 1910, III, *Britton, Earle & Wilson 5906;* palm barren east of Guanabacoa (Prov. Habana), April 2, 1910, II, III, *Britton, Earle & Wilson 6269* (host no. *6261;* Itabo (Prov. Matanzas), Nov. 12, 1915, II, *Johnston 179;* Cienfuegos (Prov. Santa Clara), Nov. 3, 1915, II, *Johnston 190;* Ceballos (Prov. Camagüey), March 23, 1916, II, III, *Johnston 510;* Las Tunas (Prov. Oriente), March 29, 1916, *Johnston 543;* Santiago de Cuba (Prov. Oriente), April 30, 1916, *Johnston 686*.

The species is autoecious, possessing pycnia, uredinia, and telia. It occurs also in Porto Rico on *S. lingulatum*, from which the type was obtained, but has not before been reported elsewhere.

77. **Puccinia barbatula** sp. nov.

ON MALPIGHIACEAE:

Banisteria laurifolia L., Paso Estancia (Prov. Oriente), May 3, 1916, O, II, III, *Johnston 678*.

Pycnia amphigenous, in small groups on brownish areas 1–3 mm. across, dark brown, noticeable, subepidermal, globoid, 70–125 μ in diameter.

Uredinia hypophyllous, few, circinating about the pycnia, oval or oblong, 0.2–0.8 mm. long, originating deep within the tissues and remaining partly covered by them, dehiscent by slit or pore, somewhat pulverulent, dark cinnamon-brown; urediniospores broadly ellipsoid or obovoid, 25–32 by 39–45 μ; wall dark cinnamon-brown, 2–2.5 μ thick, strongly and very sparsely echinulate, the echinulations colorless, 2–2.5 μ long, the pores 2, equatorial.

Telia hypophyllous, crowded about the uredinia, oval or oblong, 0.3–1 mm. long, long covered by the overarching tissues, whitish or pale brown, inconspicuous; teliospores oblong or clavate-oblong, 18–26 by 35–48 μ, rounded at both ends or slightly narrowed below, somewhat constricted at septum; wall colorless, uniformly 1.5–2.5 μ, smooth; pedicel colorless, very broad, 13–15 μ, half length of spore.

78. PUCCINIA ARECHAVELATAE Speg. An. Soc. Ci. Arg. **12**: 67. 1881.

ON SAPINDACEAE:

Cardiospermum microcarpum H.B.K.

This short-cycle rust, common in tropical America, was detected on a phanerogamic collection in the herbarium of the N. Y. Bot. Garden, obtained along the railroad near Cerro (Prov. Habana), April 13, 1903, *J. A. Shafer 183*.

Other West Indian stations are in Jamaica, Porto Rico, Antigua, and the Bahamas.

79. PUCCINIA GOUANIAE Holw. Ann. Myc. **3**: 21. 1905.

ON FRANGULACEAE (RHAMNACEAE):

Gouania lupuloides (L.) Urban (*G. domingensis* L.), Ceballos (Prov. Camagüey), Nov. 25, 1915, II, *Johnston 305*.

Gouania polygama (Jacq.) Urban (*G. tomentosa* Jacq.), without locality (Prov. Oriente), December, 1856, II, *Charles Wright 282;* Gibara (Prov. Oriente), March 15, 1903, II, III, *Holway* (Barth. N. Am. Ured. *544*); San Diego de los Baños (Prov. Pinar del Rio), Feb. 7, 1915, II, *Johnston 176;* Matanzas (Prov. Matanzas), Feb. 17, 1916, II, III, *Britton, Britton & Wilson 13999;* Los Indios, Isle of Pines, Feb. 13, II, *Britton, Britton & Wilson 14242;* San Pedro, Isle of Pines, Feb. 12–March 22, 1916, II, *Britton, Britton & Wilson 15804;* Santiago de las Vegas, Feb. 29, 1916, II, III, *Johnston 470;* Baracoa (Prov. Oriente), April 15, 1916, II, *Johnston 594, 618;* Ceiba Mocha (Prov. Matanzas), July 25, 1916, II, *Johnston 868*.

This autoecious species, having pycnia, uredinia, and telia, is discussed in the Stevens' list of Porto Rican Uredinales (Mycologia **7**: 237–238. 1915). The collection by Wright, no. 282, is the second one of the two numbers cited under the original description of *Uromyces gemmatus* B. & C. (Jour. Linn. Soc. **10**: 356. 1869), a species said to be on "the underside of leaves of *Convolvulus*, &c." The first number there cited (278) is on a Convolvulaceous host (see 51), and the second number must, therefore, represent the "&c." Wright's collection was ample, and the host was determined from material in the Curtis herbarium by Percy Wilson of the New York Garden, Jan. 13, 1915, as *Gouania polygama*. The authorities of the Kew herbarium kindly sent a fragment of 282 to the senior author, which agrees perfectly with that in the Curtis herbarium.

The species occurs on a phanerogamic specimen of *G. poly-*

gama in the herbarium of the N. Y. Bot. Garden, collected at Herradura, March 17, 1907, II, *F. S. Earle 606* (not "806" as erroneously printed in the Porto Rican list, *l. c.*, p. 237). The species occurs also in Porto Rico and in Panama.

80. **Puccinia invaginata** nom. nov.

Uredo Gouaniae Ellis & Kelsey, Bull. Torrey Club **24**: 209. 1897.

ON FRANGULACEAE (RHAMNACEAE):

Gouania lupuloides (L.) Urban (*G. domingensis* L.), Caleta Cocodrilos, Isle of Pines, March 8, 1916, II, III, *Britton, Wilson & León 15275*.

Uredinia hypophyllous, scattered, early naked, pulverulent, cinnamon-brown; paraphyses peripheral, terete to clavate, somewhat incurved, often from a branching base 9–16 by 29–45 μ, the wall colorless, thin, smooth; urediniospores introverted from the side, and appearing (with pore in optical section) arcuate to obovoid-arcuate, 16–19 by 26–31 μ, or (with pore in surface view) obovoid, 19–23 by 26–31 μ; wall cinnamon-brown, 1.5–2 μ thick, sparingly to moderately echinulate, only one pore, equatorial, on indented or flattened side.

Telia amphigenous, scattered, early naked, pulverulent, dark chocolate to blackish-brown, ruptured epidermis inconspicuous; teliospores broadly ellipsoid or broadly obovoid, 26–29 by 29–37 μ, rounded at both ends, slightly or not constricted at septum; wall dark chestnut-brown, uniformly 3–4 μ thick, moderately verrucose; pedicel colorless, 19–50 μ long, fragile.

This is the first collection of the species for Cuba and the first collection showing telia from any locality. The first uredinial collection was made on the island of St. Croix by Ricksecker in 1896 on the same host, and numerous collections have been made in Porto Rico on this host and on *G. polygama*.

81. PUCCINIA HETEROSPORA Berk. & Curt. Jour. Linn. Soc. **10**: 356. 1869.

ON MALVACEAE:

Anoda hastata Cav., Santiago de las Vegas, July 13, 1904, *Earle 235*, July 15, 1904, *Horne*, April 25, 1906, *Baker* (Barth. Fungi Columb. *2358*); Soledad Cienfuegos (Prov. Santa Clara), Nov. 5, 1915, *Johnston 197;* Ceiba Mocha (Prov. Matanzas), July 25, 1916, *Johnston 867*.

Abutilon hirtum (Lam.) Sweet, Herradura (Prov. Pinar del

Rio), Sept. 28, 1906, *Van Hermann 2991* (host no. *2996*) (Barth. Fungi Columb. *2453*); Guanajay (Prov. Pinar del Rio), Sept. 13, 1904, *Earle & Wilson 1508;* Vedado (Prov. Habana), Dec. 6, 1916, *Johnston 925.*

Abutilon indicum Sweet, Botanic Garden, Havana, March 21, 1903, *Holway* (Barth. N. Am. Ured. *240*).

Abutilon permolle (Willd.) Sweet, Gibara (Prov. Oriente), March 15, 1903, *Holway* (Barth. N. Am. Ured. *39*).

Gaya occidentalis (L.) Sweet, Santiago de las Vegas, Sept. 19, 1915, *Johnston 162*, June 25, 1916, *Johnston 851;* Tetas de Camarioca (Prov. Matanzas), Feb. 7, 9, 1916, *Britton, Britton & Wilson 14088.*

Sida glutinosa Cav., Santiago de las Vegas, Nov. 20, 1905, *Van Hermann 3373.*

Sida spinosa L. (*S. angustifolia* Lam.), Santiago de las Vegas, June 25, 1916, *Johnston 854.*

Wissadula periplocifolia (L.) Presl, Manacas (Prov. Santa Clara), Nov. 11, 1915, *Johnston 185;* Camagüey (Prov. Camagüey), Nov. 28, 1915, *Johnston 366.*

A short-cycle species without pycnia, very common throughout the warmer regions of the earth, on many malvaceous genera.

It has been seen on the following collections from Cuba in the phanerogamic herbarium of the N. Y. Bot. Garden: on *Abutilon abutiloides* (Jacq.) Garcke (*A. lignosum* Rich.), Santiago de Cuba, 1899, *V. Havard 78*, March 10–25, 1912, *Britton, Britton & Cowell 12591;* on *Abutilon hirtum* (Lam.) Sweet, Cienfuegos, Aug. 13, 1895, *Robert Combs 462;* Valley of the San Juan (Prov. Pinar del Rio), March 19, 1903, *Britton, Britton & Shafer 277;* on *Anoda hastata* Cav., Matanzas, March 16, 1903, *Britton, Britton & Shafer;* near San Luis (Prov. Oriente), Feb. 15, 17, 18, 1902, *Pollard & Palmer 293;* on *Sida procumbens* Sw., Rio Almendares to Playa de Marianao (Prov. Habana), Dec. 22–23, 1910, *Percy Wilson 9506.*

Other West Indian islands known for the species are Jamaica, Porto Rico, St. Thomas, St. Croix, and the Bahamas, but it probably occurs on many others.

82. PUCCINIA MALVACEARUM Mont. in Gay, Hist. Chile **8**: 43. 1852.

ON MALVACEAE:

Malvastrum coromandelianum (L.) Garcke, Santiago de las Vegas, May 10, 1906, *Cook.*

This widely distributed short-cycle rust, which does not produce pycnia, is here first reported for the West Indies. It was collected on the same host in Venezuela, July 15, 1913, *F. L. Stevens 2861, 2983.* It was found in Jamaica at Mandeville, on *M. corchorifolium* (Desv.) Britton, Oct., 1892, *T. D. A. Cockerell 44,* and again at the same place, Feb. 23, 1915, *E. W. D. Holway 228.*

83. PUCCINIA LUDWIGIAE (E. & E.) Holw. N. Am. Ured. **1**: 72. 1907.

ON ONAGRACEAE:

Isnardia repens (Sw.) DC., Jucaro, Isle of Pines, Feb. 20, 1916, I, *Britton, Britton & Wilson 14624.*

This is the first record for this long-cycle species outside of the United States. The host is also a new one.

84. PUCCINIA PSIDII Wint. Hedwigia **23**: 177. 1884.

ON MYRTACEAE:

Jambos Jambos (L.) Lyons (*Eugenia Jambos* L., *Jambosa vulgaris* DC.), El Yunque, Baracoa (Prov. Oriente), March 10, 1903, II, III, *Underwood & Earle 1381;* same, II, III, *Holway;* Baracoa (Prov. Oriente), April 14, 1916, *Johnston 506;* Candelaria (Prov. Pinar del Rio), Jan. 1917, II, *Horne.*

The synonymy and various notes are given in the Stevens' list of Uredinales of Porto Rico (Mycologia **7**: 239–240. 1915). The full life history of the rust is unknown. Uredinia are common and often accompanied by telia. Quite likely only pycnia are needed to complete the stages.

85. PUCCINIA HYDROCOTYLES (Link) Cooke, Grevillea **9**: 14. 1880.

ON AMMIACEAE (UMBELLIFERAE):

Hydrocotyle australis Coult. & Rose.

This imperfectly known rust is doubtless autoecious. Aecia have sometimes been referred to it, but they should more likely be associated with *Uromyces Scirpi* (Cast.) Burr. There are a number of reasons for thinking that the present species possesses only pycnia, uredinia, and telia.

The record for Cuba is based upon a phanerogamic collection in the herbarium of the N. Y. Bot. Garden from Guanabaco (Prov. Habana), April 2, 1910, II, *Britton, Earle & Wilson 6249.* No other West Indian station was known, until the 1916 collections by Whetzel and Olive in Porto Rico, although the rust is common along the eastern coast of both North and South America, notably in Central America.

86. **Puccinia Johnstonii** Arthur sp. nov.

ON SAPOTACEAE:

Dipholis salicifolia (L.) A. DC., San Diego de los Baños (Prov. Pinar del Rio), Feb. 7, 1915, II, III, *Johnston 177* (type).

Sideroxylon foetidissimum L., Santiago de las Vegas, Feb. 27, 1916, II, III, *Johnston 489.*

Uredinia hypophyllous, scattered, pustular, small, 0.2–0.3 mm. across, subepidermal, tardily naked, at first opening by a pore, becoming pulverulent, cinnamon-brown, the overarching epidermis quite persistent; paraphyses peripheral in a single row, erect, arising from a short membranous base, 2 or 3 cells deep, terete, colorless, 10–13 μ broad by 37–77 μ long, the inner wall thin, about 1 μ, the outer wall thicker, 3–7 μ; urediniospores ellipsoid or broadly obovate, 23–29 by 37–48 μ; wall cinnamon-brown, 1.5–2 μ thick, thicker above, 5–9 μ, with a lighter umbo, sparsely and strongly echinulate, the pores 4, sometimes 3, equatorial.

Teliospores in uredinial sori ellipsoid or oblong, 23–30 by 33–40 μ, rounded at both ends, not constricted at septum; wall dark chestnut-brown, uniformly 3 μ thick, sparsely and coarsely echinulate, the points 1–2 μ long; pedicel colorless, rough, 10 by 16–23 μ, the upper part swelling in water up to 16 μ, often attached somewhat obliquely.

An interesting species, showing some resemblances to *Prospodium* in the character of wall and sculpturing of the teliospores, Truly echinulate teliospores are a novelty among Uredinales. The circle of short and erect paraphyses, having a tissue-like base of somewhat elongated cells, is clearly a transitional structure between a simple ring of paraphyses and a membranous peridium having ostiolar cells larger than the others.

In naming this distinctive species the senior author takes it upon himself to use the name of Mr. J. R. Johnston in recognition of the important service he has rendered mycology in making known the rust flora of Cuba. It was at his suggestion that this summary of present knowledge was undertaken, the first attempt made to give a full list of Cuban rusts. And it has been through his untiring efforts in securing material and making observations that this considerable showing is possible. More than one third of the number (40 species) is based entirely upon material supplied by Mr. Johnston, and nearly two thirds of the total number of collections are by him. In addition to this, and even more important, he has made many observations which have added to our knowledge of life histories of different species.

87. PUCCINIA CONCRESCENS Ellis & Ev.; Arthur, Mycologia **7**: 240. 1915.

Puccinia compacta Kunze; Bubak, Hedwigia Beibl. **42**: 30. 1903. Not Berk. 1855, de Bary 1858, or Thüm. 1875.

ON ASCLEPIADACEAE:

Asclepias curassavica L.

This rather common rust of tropical America has not yet been secured in Cuba by a mycological collector, but occurs on a specimen in the phanerogamic herbarium of the N. Y. Bot. Garden, collected at Baracoa, Jan. 24–29, 1902, *Pollard, Palmer & Palmer 11.*

The species is short-cycled and a lepto-form. The history of the name is reviewed in the Stevens list of Uredinales of Porto Rico (Mycologia **7**: 240–242. 1915), where a description is given.

88. PUCCINIA GONOLOBI Rav.; Berk. Grevillea **3**: 54. 1874.

ON ASCLEPIADACEAE:

Philibertella clausa (Jacq.) Vail, Rio Gavelan (Prov. Santa Clara), March 26, 1910, *Britton, Earle & Wilson 6022;* Baracoa (Prov. Oriente), April 14, 1916, *Johnston 553;* Toa (Prov. Oriente), April 18, 1916, *Johnston 552.*

The asclepiadaceous forms of rust intended to be covered by this name include those with dark sori and ellipsoid teliospores having the septum generally transverse. The species is not well defined. It is a short-cycled lepto-form, without pycnia.

89. PUCCINIA OBLIQUA Berk. & Curt. Jour. Linn. Soc. **10**: 356. 1858.

Puccinia Cynanchi Lagerh. Bol. Soc. Brot. **7**: 129. 1889.

Puccinia sphaerospora Syd. & Henn. Ann. Myc. **1**: 327. 1903.

ON ASCLEPIADACEAE:

Fischeria crispiflora (Sw.) Schl., near Los Indios, Isle of Pines, May 20, 1910, *O. E. Jennings 439* (host no. *438*); Santa Barbara, Isle of Pines, Feb. 23, 1916, *Britton, Britton & Wilson 14784;* Santa Fé, Isle of Pines, Feb. 27, March 1, 1916, *Britton, Britton & Wilson 15108;* Saetia (Prov. Oriente), April 9, 1916, *Johnston 551.*

[*Metastelma penicillatum* Griseb.?] without locality (Prov. Oriente), 1857, *Charles Wright.*

The species is autoecious, and similar in habit and gross appearance to *Puccinia Gonolobi* Rav., but as here used is intended to include those forms having mostly globoid teliospores, with moderately thick walls, and oblique septa in most instances. The type of the species was collected in Cuba by Charles Wright on some undetermined host, locality not given. Upon request the material at the Kew herbarium was examined, and the opinion given that the host appears to be a species of *Metastelma*, probably *M. penicillatum* Griseb. There are, however, at least two collections at Kew. The type cited in the Fungi Cubenses (page 356) is no. 281. This may be the one which is thought to be on *Metastelma penicillatum*, and is listed above. Another collection bears the number 288, but is without year or locality other than "Cuba." A leaf from this collection, kindly sent to the senior author from Kew, well answers to the statement with the original description as a leaf "of some plant resembling chickweed."

90. PUCCINIA CRASSIPES Berk. & Curt. Grevillea **3**: 54. 1874.

ON CONVOLVULACEAE:

Ipomoea cathartica Poir. (*I. acuminata* R. & S., not Ruiz & Pav.), Santiago de las Vegas, Aug. 20, 1904, I, *Earle & Wilson 1140* (Barth. Fungi Columb. *2456*), Sept. 3, 1904, I, *Abarca 1361*, Nov. 20, 1904, I, III, *Earle 5190.*

Ipomoea triloba L., Santiago de las Vegas, Nov. 25, 1916, I, *Johnston 923*, Nov. 29, 1917, III, *Johnston 952.*

An autoecious species with aecia and telia, but having no uredinia. It flourishes especially in warm regions, and has been reported from St. Croix and Porto Rico, and also from the adjoining continent of North America.

91. **Puccinia megalospora** (Orton) comb. nov.

Allodus megalospora Orton, Mem. N. Y. Bot. Gard. **6**: 198. 1916.

ON CONVOLVULACEAE:

Ipomoea carolina L., Hanabanilla Falls, Trinidad Mts. (Prov. Santa Clara), March 1–2, 1910, I, *Britton, Earle & Wilson 4827;* Santa Barbara, Isle of Pines, Feb. 12–March 22, 1916, I, *Britton, Britton & Wilson 14786.*

This autoecious rust resembles *Puccinia crassipes* in the absence of uredinia, and also in gross appearance, but possesses much larger aeciospores, and teliospores more thickened at the apex. The Cuban stations are the only ones known for it outside of Mexico.

92. PUCCINIA LANTANAE Farl. Proc. Amer. Acad. Sci. **18**: 83. 1883.

ON VERBENACEAE:

Lantana Camara L., Holguin (Prov. Oriente), March 17, 1903, *Holway* (Barth. N. Am. Ured. *645*).

Lantana involucrata L. (*L. odorata* L.), hills near Santiago de las Vegas, May 14, 1903, *Baker 2869;* Playa Marianao (Prov. Habana), Oct. 31, 1915, *Johnston 240;* Vanadero (Prov. Matanzas), Feb. 8, 1916, *Britton & Wilson 14049;* Saetia (Prov. Oriente), April 8, 1916, *Johnston 557.*

Lantana reticulata Pers., Marianao (Prov. Habana), Aug. 13, 1916, *Johnston 870.*

Lippia dulcis Trev., Paso Estancia (Prov. Oriente), March 3, 1916, *Johnston 680*, May 3, 1916, *Johnston 703.*

Lippia stoechadifolia H.B.K., San Luis (Prov. Oriente), February, 1902, *Pollard & Palmer 308;* Santiago de Cuba (Prov. Oriente), March 6, 1903, *Holway* (Barth. N. Am. Ured. *749*).

Priva lappulacea (L.) Pers., El Yunque, Baracoa (Prov. Oriente), March 10, 1903, *Holway.*

This short-cycle species, common on many hosts in tropical America, has been detected also on *Lantana trifolia* L. in the phanerogamic herbarium of the N. Y. Bot. Garden, Santiago de Cuba (Prov. Oriente), April 26, 1902, *S. H. Hamilton 46*, and in the same herbarium on *L. reticulata* Pers., El Moro to Cojimar (Prov. Habana), Dec. 8, 1910, *P. Wilson 9134;* San Juan, Isle of Pines, March 15, 17, 1916, *Britton, Britton & Wilson 14981.*

It has also been taken in Jamaica, Porto Rico, St. Thomas and the Bahamas.

93. PUCCINIA URBANIANA P. Henn. Hedwigia **37**: 278. 1898.

ON VERBENACEAE:

Valerianodes jamaicensis (L.) Medic. (*Abena jamaicensis* Hitch., *Stachytarpheta jamaicensis* Vahl), Santiago de Cuba (Prov. Oriente), March 6, 1903, *Holway;* Batabano (Prov. Habana), March 20, 1906, *Baker 2767;* Consolación del Sur (Prov. Pinar del Rio), Feb. 2, 1915, *Johnston 152;* Santiago de las Vegas, Oct. 2, 1915, *Johnston 154;* Baracoa (Prov. Oriente), April 14, 1916, *Johnston 606.*

A short-cycle species occurring also in Porto Rico and the Bahamas, as well as in southern Florida.

94. PUCCINIA SALVIICOLA Diet. & Holw. Bot. Gaz. **24**: 33. 1897.

ON LAMIACEAE (LABIATAE):

Salvia occidentalis Sw., Marianao (Prov. Habana), Feb. 6, 1916, *Johnston 442;* San Pedro, Isle of Pines, Feb. 12–March 22, 1916, II, *Britton & Wilson 142070;* Ceballos (Prov. Camagüey), March 24, 1916, II, *Johnston 524;* Sabanilla (Prov. Oriente), April 22, 1916, II, *Johnston 593.*

Only uredinia were found, and these not abundant. The species also occurs in Porto Rico and Jamaica. The full life cycle is unknown, but probably pycnia and aecia are sometimes formed.

95. PUCCINIA MEDELLINENSIS Mayor, Mém. Soc. Neuch. Sci. Nat. **5**: 497. 1913.

ON LAMIACEAE (LABIATAE):

Mesosphaerum pectinatum (Poir.) Kuntze (*Hyptis pectinata* Poir.), Cienfuegos (Prov. Santa Clara), Nov. 3, 1915, *Johnston 196;* Matanzas (Prov. Matanzas), Feb. 7, 1916, II, *Britton, Britton & Wilson 13995.*

Mesosphaerum suaveolens (L.) Kuntze (*Hyptis suaveolens* Poir.), Santiago de Cuba (Prov. Oriente), March 6, 1903, II, *Holway;* Marianao (Prov. Habana), Oct. 31, 1915, *Johnston 241;* Cienfuegos (Prov. Santa Clara), Nov. 3, 1915, II, *Johnston 244;* Tetas de Camarioca (Prov. Matanzas), Feb. 7, 9, 1916, II, *Britton, Britton & Wilson 14089*; San Juan, Isle of Pines, March 15, 17, 1916, II, *Britton, Britton & Wilson 15461.*

Apparently a common autoecious species throughout the West Indian islands, but on *M. suaveolens* only uredinia have been found. In the North American Flora (**7**: 212–213. 1912) this species is confused with *Eriosporangium tucumanense* (Speg.) Arth., a South American species not yet found in North America. The description following that name applies to *P. medellinensis,* but should give the pores of the urediniospores as *2 or sometimes 3.*

96. PUCCINIA HYPTIDIS (M. A. Curt.) Tracy & Earle, Bull. Miss. Exp. Sta. **34**: 86. 1895.

ON LAMIACEAE (LABIATAE):

Mesosphaerum capitatum (L.) Kuntze (*Hyptis capitata* Jacq.), Baracoa (Prov. Oriente), March 9, 1903, II, *Holway;* Paso Estancia (Prov. Oriente), May 3, 1916, II, *Johnston 695.*

This autoecious species has not yet been taken in the West Indies in any but the uredinial stage, although known from the southern United States on *M. rugosum* (*Hyptis radiata*) bearing pycnia, aecia, and telia, as well as uredinia. The other West Indian stations are in Jamaica and Porto Rico. The record of *Hyptis suaveolens,* as a host under this species in the North American Flora (**7**: 212), is an error. It belongs under *P. medellinensis,* as given above.

97. PUCCINIA INSITITIA Arth. Mycologia **7**: 248. 1915.

ON LAMIACEAE (LABIATAE):

Mesosphaerum lantanifolium (Poir.) Kuntze (*Hyptis lantanifolia* Poir.), Santa Ana, Isle of Pines, March 20, 1916, II, *Britton & Wilson 15668.*

This long-cycle species is founded on a collection from Brazil, and has also been found in Porto Rico. Only uredinia and telia are known.

98. PUCCINIA LEONOTIDIS (P. Henn.) Arth. Mycologia **7**: 245. 1915.

ON LAMIACEAE (LABIATAE):

Leonotis nepetaefolia (L.) Br., Botanic Garden, Havana, March 21, 1903, II, *Holway* (Barth. N. Am. Ured. *781*); Vedado (Prov. Habana), Nov. 23, 1916, II, *Johnston 922*.

This autoecious species, occurring throughout the warmer regions of the world, has been found in America only in the uredinial stage. Aecia and telia have been seen from Africa. The other West Indian islands represented are Jamaica, Porto Rico, and the Bahamas.

99. PUCCINIA GLOBOSIPES Peck, Bull. Torrey Club **12**: 34. 1885.

ON SOLANACEAE:

Lycium carolinianum Walt., Rio Gavelan (Prov. Santa Clara), March 26, 1910, II, *Britton, Earle & Wilson 6028* (host no. *6027*).

An autoecious species with pycnia, uredinia, and telia, now first reported for the West Indies. It is elsewhere known from Alabama, Kansas, and Utah to the Mexican boundary, and as far west as southern California.

100. **Puccinia Adenocalymnatis** (P. Henn.) comb. nov.

Uredo Adenocalymnatis P. Henn. Hedwigia **35**: 249. 1896.

Puccinia aequinoctialis Holw. Ann. Myc. **3**: 22. 1905.

ON BIGNONIACEAE:

Cydista aequinoctialis (L.) Miers (*Bignonia aequinoctialis* L.), Baracoa (Prov. Oriente), March 13, 1903, II, III, *Holway* (Barth. N. Am. Ured. *525*).

An imperfectly understood species. Only three collections are known, two being from the West Indies, and on the same host. The collection here cited shows a few teliospores and a good development of uredinia, and a collection from Porto Rico shows uredinia only. The beginning stage of the life cycle has not yet been discovered. A collection from Brazil on *Adenocalymna*, *E. Ule 902*, shows uredinia that appear to be the same as those of the West Indian form. The spores on the fragmentary part of the specimen examined are a trifle smaller, but the measurements given by Hennings are the same as those taken from the West Indian material. As *Adenocalymna* is closely related to *Cydista*, there appears no good reason for doubting the identity of the two rusts, and they are therefore here united under one name. These rusts were inadvertently placed by the senior author (Mycol. **9**: 83. 1917) under *Puccinia cuticulosa* Arth. (*Uredo cuticulosa* E. & E.), a Nicaraguan rust, recently found to be identical with *Prospodium appendiculatum* (Wint.) Arth.

101. PUCCINIA RUELLIAE (Berk. & Br.) Lagerh. Tromsö Mus. Aarsh. **17**: 71. 1895.

ON ACANTHACEAE:

Blechum Brownei (Sw.) Juss., Santiago de las Vegas, Feb. 10, 1916, II, III, *Johnston 445*.

This species possesses all spore forms. It occurs also in Porto Rico, Martinique, and in Central and South America on the same host. Only uredinia have been seen on North American collections on this host until the present collection came to hand, which gave a few telia. It is now evident that the rust, heretofore listed as *P. Blechi* Lagerh., is identical with that on *Ruellia*, and other hosts, often listed under the name *P. lateripes* Berk. & Rav.

102. PUCCINIA LATERITIA Berk. & Curt. Jour. Acad. Sci. Phila. **2**: 281. 1853.

ON RUBIACEAE:

Borreria laevis (Lam.) Griseb., Baracoa (Prov. Oriente), April 15, 1916, *Johnston 503*.

Hemidiodia ocimifolia (Willd.) K. Schum., El Yunque, Baracoa (Prov. Oriente), March 10, 1903, *Holway*.

The species is a short-cycle form without pycnia. It is a common rust of warm regions, and is known from other West Indian islands on the genera *Diodia*, *Ernodia*, *Mitracarpum*, and *Spermacoce*. It has been reported from Jamaica, Porto Rico, and the Bahamas.

103. PUCCINIA XANTHII Schw. Schr. Nat. Ges. Leipzig **1**: 73. 1822.

ON AMBROSIACEAE:

Xanthium longirostre Wallr., Santiago de las Vegas, June, 1905, *Horne;* July 21, 1915, *P. Cardin* (*Johnston 168*), Oct. 1916, *Johnston 3, 4, 5, 13, 15, 16, 17;* Baracoa (Prov. Oriente), April 15, 1916, *Johnston 595*.

Xanthium saccharatum Wallr., Santiago de las Vegas, Oct. 1916, *Johnston 2, 6, 9, 10, 12, 14.*

Xanthium intermediate between *X. longirostre* and *X. saccharatum,* Santiago de las Vegas, Oct. 1916, *Johnston 1, 8, 11.*

The species has been detected on the first host also on a phanerogamic specimen in the herbarium of the N. Y. Bot. Garden, collected at Paso Estancia (Prov. Oriente), Aug. 30, 1909, *J. A. Shafer 1672.*

The species, which is short-cycled and without pycnia, is a common American rust, but rather rare in the West Indian islands, the other stations being in Jamaica, Porto Rico, and Bermuda, and in each instance on *X. longirostre.*

104. **Puccinia fuscella** sp. nov.

ON CARDUACEAE:

Vernonia menthaefolia Less., El Yunque, Baracoa (Prov. Oriente), March 10, 1903, II, III, *Holway* (type), April 18, 1916, II, III, *Johnston 584.*

Uredinia hypophyllous, scattered, roundish, punctiform, minute, 0.1–0.2 mm. across, early naked, pulverulent, light cinnamon-brown, ruptured epidermis noticeable; urediniospores broadly ellipsoid or obovoid, 23–29 by 26–32 μ; wall light cinnamon-brown, moderately thick, 2–3 μ, echinulate, the pores indistinct, probably 4–6, and scattered.

Telia hypophyllous, scattered, or crowded in groups of two or three sori, irregularly roundish, small, 0.2–0.3 mm. across, rather early naked, dark chestnut-brown, ruptured epidermis inconspicuous; paraphyses peripheral, hyphoid, colorless, thin-walled, short and inconspicuous; teliospores oblong, 21–27 by 40–48 μ, slightly constricted at septum, rounded or obtuse at both ends; wall cinnamon-brown, 1.5–2 μ, thicker above, 5–9 μ including a semihyaline umbo, minutely verrucose above, appearing smooth; pedicel colorless, two thirds length of spore or less, fragile.

Closely related to *Puccinia Vernoniae* Schw., but differs in the uredinial pore-arrangement and other minute characters. The type collection was issued as no. *772* in Bartholomew's North American Uredinales, under the name *P. Vernoniae.*

105. PUCCINIA EVADENS Harkn. Bull. Calif. Acad. Sci. 1: 34. 1884.

Eriosporangium evadens Arth. Résult. Sci. Congr. Bot. Vienne 343. 1906.

ON CARDUACEAE:

Baccharis sp., Santa Clara (Prov. Santa Clara), March 22, 1903, II, III, *Holway.*

The species is autoecious, pycnia, aecia, uredinia, and telia all being known, and is found in southern California and Arizona to Central Mexico. The collection here listed is the only one known from the West Indies.

106. PUCCINIA ABRUPTA Diet. & Holw. Hedwigia **37**: 208. 1898.

ON CARDUACEAE:

Viguiera helianthoides H.B.K., Santiago de las Vegas, Feb. 28, 1906, III, *Baker 2682;* Marianao (Prov. Habana), Aug. 13, 1916, II, *Johnston 869.*

The species is probably autoecious, although no pycnia or aecia have yet been seen. The collection by Baker is unique in producing a fusiform swelling of the stem full two inches long and twice the normal diameter of the stem. The uredinia have been rarely seen. It was detected in the phanerogamic herbarium of the N. Y. Bot. Garden, on the same host from Sierra de Anafe (Prov. Pinar del Rio), Dec. 1911, II, *P. Wilson.* The species is now first reported for the West Indies.

107. PUCCINIA HELIANTHI Schw. Schrift. Nat. Ges. Leipzig **1**: 68. 1822.

ON CARDUACEAE:

Helianthus annuus L., Santiago de las Vegas, June 15, 1905, II, *Horne.*

The collection of this autoecious rust, the only one seen from the West Indies, was obtained in the garden of the Cuban Experiment Station. It shows an abundance of sori, but only uredinia. The species is cosmopolitan, and produces pycnia, aecia, uredinia, and telia in the life cycle.

108. PUCCINIA CONOCLINII Seym. Bot. Gaz. **9**: 191. 1884.

ON CARDUACEAE:

Ageratum maritimum H.B.K., Caleta Cocodrilos, Isle of Pines, March 8, 1916, II, III, *Britton, Wilson & León 15311.*

Eupatorium villosum Sw., Gibara (Prov. Oriente), March 15, 1903, II, *Holway;* Santiago de las Vegas, April 5, 1906, II, *Horne,* Feb. 28, 1916, II, *S. C. Bruner* (*Johnston 476*).

This autoecious rust occurs on many hosts in the warmer parts of America. Its aecia are not known, although *Aecidium roseum* Diet. & Holw. was for a time supposed to belong with it, and it has often been listed as *P. rosea.* A collection from Cuba was found in the phanerogamic herbarium of the N. Y. Bot. Garden, from Cabañas Bay (Prov. Oriente), on *E. villosum,* March 17–20, 1912, II, *Britton & Cowell 12816.* Porto Rico is the only other West Indian island at present represented.

109. PUCCINIA SYNEDRELLAE P. Henn. Hedwigia **37**: 277. 1898.

Puccinia solida Berk. & Curt. Jour. Linn. Soc. **10**: 356. 1869. Not *P. solida* Schw. 1832.

Puccinia Tridacis Arth. Bull. Torrey Club **33**: 156. 1906.

Puccinia Eleutheranthera Diet. Ann. Myc. **7**: 354. 1909.

ON CARDUACEAE:

Eleutheranthera ruderalis (Sw.) Sch. Bip., without locality (Prov. Oriente), 1856–7, *Charles Wright 276;* Vivijagua, Isle of Pines, Feb. 28, 29, 1916, *Britton, Britton & Wilson 15071,* March 18, 20, 1916, *Britton & Wilson 15608;* Maravi, Baracoa (Prov. Oriente), April 18, 1916, *Johnston 604.*

Emilia sonchifolia (L.) DC., Ceballos (Prov. Camagüey), Nov. 24, 1915, *Johnston 304;* Canet (Prov. Camagüey), Dec. 1, 1915, *Johnston 280;* Nuevitas (Prov. Camagüey), Dec. 3, 1915, *Johnston 383;* San Pedro, Isle of Pines, Feb. 12–March 22, 1916, *Britton & Wilson 14465;* Columbia, Isle of Pines, March 19, 21, 1916, *Britton, Britton & Wilson 15793;* Paso Estancia (Prov. Oriente), May 3, 1916, *Johnston 704;* Baracoa (Prov. Oriente), April 15, 1916, *Johnston 585,* April 17, 1916, *Johnston 566, 628.*

Neurolaena lobata (L.) R. Br., El Yunque, Baracoa (Prov. Oriente), March 12, 1903, *Holway;* Jucaro, Isle of Pines, Feb. 20, 1916, *Britton, Britton & Wilson 14613.*

Synedrella nodiflora (L.) Gaertn., Cojimar (Prov. Habana), Aug. 24, 1910, *Britton, Earle & Gager 6272* (host no. *6271*); Santiago de las Vegas, Oct. 2, 1915, *Johnston 155;* Taco Taco (Prov. Pinar del Rio), Sept. 17, 1916, *Johnston 877.*

Tridax procumbens L., Punta Brava (Prov. Pinar del Rio), Nov. 15, 1904, *Baker & O'Donovan 4039;* Matanzas (Prov. Matanzas), Feb. 7, 1916, *Britton, Britton & Wilson 13997;* Columbia, Isle of Pines, Feb. 20, 1916, *Britton, Britton & Wilson 14664.*

This species, common in the West Indies, is a short-cycle leptoform, without pycnia. It has been detected on phanerogamic specimens in the herbarium of the N. Y. Bot. Garden, on *Eleutheranthera ruderalis,* near Gerona, Isle of Pines, May 8, 1904, *A. H. Curtiss 488;* Guantanamo Bay, March 17–30, 1909, *N. L. Britton 2243;* on *Tridax procumbens,* Santiago de Cuba, March, 1903, *Underwood & Earle 125;* and on *Neurolaena lobata,* from "Cuba Orientale," 1856–7, *Charles Wright 772.*

The type of *Puccinia solida* B. & C. was collected by Charles Wright in "Cuba Orientale," 1856–7, and the host was first determined in January, 1910, from the specimen in the Curtis herbarium at Harvard University, by B. L. Robinson of the Gray herbarium, who found it to be *E. ruderalis.*

Other West Indian islands now represented are Jamaica, Porto Rico, St. Domingo, Guadeloupe, Martinique, Grenada, Antigua, Barbados, and Tortola, being the most extensive West Indian record for any species of rust up to the present time.

110. PUCCINIOSIRA PALLIDULA (Speg.) Lagerh. Tromsö Mus. Aarsh. **16**: 122. 1894.

ON TILIACEAE:

Triumfetta semitriloba L., Itabo (Prov. Matanzas), Nov. 12, 1915, *Johnston 178;* Ceballos (Prov. Camagüey), Nov. 25, 1915, *Johnston 303;* Minas (Prov. Camagüey), Dec. 2, 1915, *Johnston 372;* Santiago de las Vegas, Dec. 3, 1916, *Johnston 930.*

A short-cycle species, not very conspicuous, and probably more common than the few collections known would indicate. It also occurs in Porto Rico, Jamaica, Guadeloupe, and in Guatemala and South America.

111. ENDOPHYLLUM CIRCUMSCRIPTUM (Schw.) Whetzel & Olive, Am. Jour. Bot. **4**: 49. 1917.

Aecidium circumscriptum Schw.; Berk. & Curt. Jour. Acad. Sci. Phila. **2**: 283. 1853.

Aecidium Cissi Wint. Hedwigia **23**: 168. 1884.

ON VITACEAE:

Cissus sicyoides L., Baracoa (Prov. Oriente), April 14, 1916, *Johnston 502.*

This short-cycle rust has been considered until recently a stage of a heteroecious species. It is known from Jamaica and Porto Rico, and from Panama and the northern border of South America.

112. BOTRYORHIZA HIPPOCRATEAE Whetzel & Olive, Am. Jour. Bot. **4**: 47. 1917.

ON CELASTRACEAE:

Hippocratea volubilis L., Alto Cedro (Prov. Oriente), March, 1903, *Underwood & Earle 1636;* Baracoa (Prov. Oriente), April 15, 1916, *Johnston 633.*

A peculiar white-spored rust, formed on hypertrophied areas. It also occurs abundantly in Porto Rico, but has not been reported elsewhere.

113. **Aecidium Pisoniae** sp. nov.

ON NYCTAGINACEAE:

Pisonia aculeata L., Ceballos (Prov. Camagüey), Nov. 25, 1915, *Johnston 298.*

Pycnia amphigenous, few, on discolored spots, noticeable, subepidermal, globose, 96–128 μ in diameter; ostiolar filaments 64–80 μ long.

Aecia hypophyllous, crowded in groups 3–5 mm. across, cupulate, 0.1–0.2 mm. in diameter; peridium colorless, the margin somewhat recurved, erose, the peridial cells rhomboidal in radial section, 12–16 by 16–34 μ, abutted, the wall evenly thick, 1.5–2 μ, the outer wall smooth, the inner wall very finely and closely verrucose; aeciospores globoid or short-oblong, 15–16 by 16–23 μ; wall nearly colorless, thin, about 1 μ, very finely and closely verrucose.

The rust has been collected only once. Early in July, 1916, the junior author visited the locality where he had first found it the year before, and discovered that the forest had been cut down and burned off preparatory to planting cane. The host is abundant in the vicinity, but no rust could be detected upon other plants of it. The germination of the spores has not yet been studied, and the assignment to the genus is based upon superficial characters only. If correctly placed, it is probably heteroecious.

114. AECIDIUM PASSIFLORIICOLA P. Henn. Hedwigia **43**: 168. 1904.

ON PASSIFLORACEAE:

Passiflora rubra L., Ceballos (Prov. Camagüey), July 6, 1916, *Johnston 862.*

This rust appears to be quite local. It has been collected in Porto Rico and Jamaica, and also in Peru, S. A. It is undoubtedly heteroecious. According to observations made by Whetzel and Olive in Porto Rico during March and April, 1916 (Mycologia **9**: 75. 1917), it probably is the aecial form of *Puccinia Scleriae* (Paz.) Arth., a rust which has not so far been found in Cuba.

115. AECIDIUM TOURNEFORTIAE P. Henn. Hedwigia **34**: 338. 1895.

ON BORAGINACEAE:

Tournefortia hirsutissima L., Baracoa (Prov. Oriente), April 14, 1916, *Johnston 505;* Paso Estancia (Prov. Oriente), May 3, 1916, *Johnston 706.*

Tournefortia peruviana Poir., Ceballos (Prov. Camagüey), July 6, 1916, *Johnston 863.*

The rust is probably the aecial stage of some heteroecious species. It has been observed on a phanerogamic specimen in the herbarium of the N. Y. Bot. Garden, collected at Vento (Prov. Habana), July 1, 1904, *P. Wilson 576.* It occurs also in Porto Rico and in South America.

116. AECIDIUM TUBULOSUM Pat. & Gaill. Bull. Soc. Myc. Fr. **4**: 97. 1888.

ON SOLANACEAE:

Solanum torvum Sw., Aguacate (Prov. Habana), March 23, 1903, *Holway;* Jamal (Prov. Oriente), April 21, 1916, *Johnston 513.*

A very abundant rust in some localities in the tropics, and doubtless heteroecious with the alternate form on a grass or sedge. It is known also from Jamaica, Porto Rico, as well as from Central and South America.

117. **Aecidium simplicius** sp. nov.

ON BIGNONIACEAE:

Tecoma pentaphylla (L.) Juss., Taco (Prov. Oriente), April 18, 1916, *Johnston 518.*

Aecia hypophyllous, scattered or indefinitely grouped, cupulate, short, 0.08–0.15 mm. in diameter; peridium white, margin erect, lacerate, the peridial cells rhomboidal, 21–29 µ long, slightly or not overlapping, the outer wall rather thick, 4–7 µ, the inner wall somewhat thinner, 2.5–4 µ, rugose; aeciospores globoid, 21–26 by 25–29 µ; wall colorless, rather thin, 1–1.5 µ, very finely and closely verrucose.

The material on which this species is founded is scanty, being only a few small leaves from seedlings. The aecia on them are, however, quite numerous. In reference to the host, and the place where it was found, the collector has the following to say.

"In regard to the host there seems to be little chance for mistake. The seedlings have 3–5 leaflets identical with those of *Tecoma*. The leaflets are very narrow but so are they on the mature flowering plants in this locality, that is to say on the first branches. The later leaflets become of a normal width. In one case the same fungus was found on one leaf of a plant 2 feet high, while the most of them had only the cotyledonary leaves or perhaps the second and third pair affected.

"The location of this plant was unique—in the basin at the foot of a waterfall about a hundred feet high, with constantly moist condition about the basin. Seedlings were growing on the moss-covered rocks, and mature plants overhanging the boulders in the river. It is regretable that the locality is so isolated."

Assuming that this form is a genuine aecium, for the spores have not yet been germinated, the probability of its being autoecious or heteroecious remains an open question.

118. AECIDIUM FARAMEAE Arth. Bull. Torrey Club **42**: 592. 1915.

ON RUBIACEAE:

Faramea occidentalis (L.) A. Rich., San Diego de los Baños (Prov. Pinar del Rio), Aug. 31–Sept. 3, 1910, *Britton, Earle & Gager 6855*.

Only the type collection cited above is known. The germination of the spores has not yet been observed, and it is by no means certain that it is not a species of *Endophyllum*. The more succulent part of the host is often greatly distorted by the rust.

Form-genus UREDO, with paraphyses imbricated to form a pseudo-peridium, or with cells united into a peridial membrane, mostly forms belonging to UREDINACEAE (MELAMPSORACEAE), nos. 119–121.

119. UREDO ARTOCARPI R. & Br. Jour. Linn. Soc. Bot. **14**: 93. 1873.

Physopella (?) *Artocarpi* Arth. N. Am. Flora **7**: 103. 1907.

ON ARTOCARPACEAE:

Artocarpus incisa L.f., Baracoa (Prov. Oriente), April 14, 1916, *Johnston 500.*

Castilla elastica Cerv., Santiago de las Vegas, Jan. 30, 1916, *Johnston 464.*

Heretofore the only American station known for this tropical rust was in Porto Rico on *Artocarpus communis.* Only urediniospores have yet been detected, and its affinities are very uncertain.

120. UREDO COCCOLOBAE P. Henn. Hedwigia **35**: 253. 1896.

ON POLYGONACEAE:

Coccolobis Uvifera (L.) Jacq., Marianao (Prov. Habana), Feb. 6, 1916, *Johnston 440;* Santiago de las Vegas, May 13, 1916, *Johnston 699.*

The rust also occurs in Porto Rico, and in South America.

121. UREDO JATROPHICOLA Arth. Mycologia **7**: 331. 1915.

ON EUPHORBIACEAE:

Jatropha Curcas L., Santiago de las Vegas, Oct. 24, 1915, *Johnston 127;* Saetia (Prov. Oriente), April 8, 1916, *Johnston 514.*

Jatropha gossypifolia L., Soledad, Cienfuegos (Prov. Santa Clara), Nov. 5, 1915, *Johnston 208;* Baracoa (Prov. Oriente), April 14, 1916, *Johnston 587.*

This unconnected form has been found in the phanerogamic herbarium of the N. Y. Bot. Garden on *Jatropha gossypifolia* from Havana, April 7, 1903, *J. A. Shafer 86*, and from Rio Togaba, Trinidad (Prov. Santa Clara), March 15, 1910, *Britton & Wilson 5549.*

The rust is also known from Porto Rico and St. Domingo.

Form-genus UREDO, with paraphyses absent, or if present, free and peripheral, mostly forms belonging to AECIDIACEAE (PUCCINIACEAE), nos. 122–140.

122. UREDO GYMNOGRAMMES P. Henn. Hedwigia **34**: 337. 1895.

ON POLYPODIACEAE:

Pityrogramma calomelanos (L.) Link (*Gymnogramma calomelanos* Kaulf.), El Yunque, Baracoa (Prov. Oriente), March 10, 1903, *Holway.*

This imperfectly known fern rust has been collected in Jamaica and Porto Rico on numerous hosts.

123. UREDO PASPALICOLA P. Henn. Hedwigia **44**: 57. 1905.

Uredo Stevensiana Arth. Mycologia **7**: 326. 1915.

ON POACEAE:

Bambos vulgaris Schrad., Santiago de las Vegas, Jan. 29, 1916, *Johnston 424*.

Leptochloa domingensis (Jacq.) Trin., Antilla (Prov. Oriente), April 8, 1916, *Johnston 542*.

Paspalum conjugatum Berg., Herradura (Prov. Pinar del Rio), March, 1917, *Horne*.

This imperfectly known, pale-spored, South American rust, recently recognized from Porto Rico and Guatemala, is now first recorded for Cuba. The second Cuban host is a new one for the species.

124. UREDO FUIRENAE P. Henn. Hedwigia Beibl. **38**: 70. 1899.

ON CYPERACEAE:

Fuirena umbellata Rottb., Batabano (Prov. Habana), Oct. 3, 1904, *Baker & Wilson 2214* (host no. *2213*); Herradura (Prov. Pinar del Rio), March 30, 1907, *Earle 652;* Siguanea, Isle of Pines, March 12, 1916, *Britton, Britton & Wilson 15387*.

This imperfectly known rust has been found in Porto Rico, Brazil and India, in each instance on *Fuirena umbellata*, and only with urediniospores.

125. UREDO SUPERIOR Arth. Bull. Torrey Club **31**: 5. 1904.

ON CYPERACEAE:

Fimbristylis ferruginea (L.) Vahl, Saetia (Prov. Oriente), April 8, 1916, *Johnston 646*.

The species is elsewhere known only from Porto Rico.

126. UREDO DIOSCOREAE P. Henn. Hedwigia **35**: 255. 1896.

ON DIOSCOREACEAE:

Dioscorea sp., El Yunque, Baracoa (Prov. Oriente), March 12, 1903, *Holway*.

Rajania cordata L., Toa (Prov. Oriente), April 18, 1916, *Johnston 554*.

The reexamination of all West Indian collections of *Dioscorea* rust seems to indicate that, while there is some variation as to size of urediniospores and thickness of walls, yet all may be considered to be one species, and also to be the same as the type material of *Uredo Dioscoreae* P. Henn. from Brazil. The surface of the spores is conspicuously echinulate (not "verrucose," as erroneously stated in the Uredinales of Porto Rico (Mycologia **7**: 320. 1915)), and the pores indistinct but probably two and equatorial, or somewhat superequatorial.

Puccinia valida Arth., on *Dioscorea convolvulacea*, from Jalapa, Mexico, has uredinia that in both gross and microscopic appearance agree quite well with the West Indian material. The chief differences, aside from being intermixed with the telia, are the darker and thicker walls of some of the urediniospores. There are good reasons for thinking that all the West Indian collections belong to some *Uromyces* or *Puccinia*, possibly to the Mexican species of *Puccinia*.

127. UREDO GYNANDREARUM Corda, Icones Fung. **3**: 3. 1839.

ON ORCHIDACEAE:

Habenaria maculosa L.

This imperfectly known orchid rust was observed on a phanerogamic specimen in the herbarium of the N. Y. Bot. Garden, collected on the side and top of El Yunque (Prov. Oriente), Dec. 30, 1910, *J. A. Shafer 7992*. It is known also from Porto Rico and Trinidad, and from Central and South America.

128. UREDO NIGROPUNCTATA P. Henn. Hedwigia **35**: 254. 1896.

ON ORCHIDACEAE:

Bletia patula Hook.

This imperfectly known orchid rust was observed on a phanerogamic collection in the herbarium of the N. Y. Bot. Garden, collected upon El Yunque, Baracoa (Prov. Oriente), March, 1903, *Underwood & Earle 929*. It is also known from Porto Rico, Haiti, the Bahamas, and from Florida and South America.

129. UREDO CHERIMOLIAE Lagerh. Bull. Soc. Myc. Fr. **11**: 215. 1895.

ON ANNONACEAE:

Annona reticulata L., Santiago de las Vegas, March 2, 1916, *Johnston 492*.

Annona squamosa L., Santiago de las Vegas, June 25, 1916, *Johnston 848*, Nov. 3, 1917, *Johnston 951*.

The species has, heretofore, been known only from Ecuador, S. A., and on *A. Cherimolia*. It is well characterized, and easily separated from other species of *Uredo* on similar hosts, by the thin-walled spores and the greatly thickened extremities of the paraphyses.

130. UREDO BAUHINIICOLA P. Henn. Hedwigia **34**: 98. 1895.

ON CAESALPINIACEAE (CASSIACEAE):

Bauhinia heterophylla Kunth, Aguacate (Prov. Habana), March 23, 1903, *Holway;* Guanajay (Prov. Pinar del Rio), Sept. 13, 1904, *Earle 1499;* Candelaria (Prov. Pinar del Rio), Jan. 1917, *Horne.*

The type of this imperfectly known rust was obtained by Ule in Brazil, on *Bauhinia rubiginosa* Bong. It is here first reported for North America. The spores have three equatorial pores, usually to be seen without difficulty. Paraphyses are absent. The form is probably a stage of some *Uromyces.*

131. UREDO HYMENAEAE Mayor, Mém. Soc. Neuch. Sci. **5**: 585. 1913.

ON CAESALPINIACEAE (CASSIACEAE):

Hymenaea Courbaril L., Ceballos (Prov. Camagüey), Nov. 26, 1915, *Johnston 296.*

This imperfectly known rust occurs also in Porto Rico and South America. It may belong to the genus *Ravenelia.*

132. UREDO ARACHIDIS Lagerh. Tromsö Mus. Aarsh. **17**: 106. 1894.

ON FABACEAE:

Arachis hypogea L., Santiago de las Vegas, Sept. 27, 1915, *Johnston 164.*

This slightly known rust is also reported from Porto Rico, Guadeloupe, and Grenada, as well as from Trinidad and the continent of South America. It has also been sent to the senior author by Mr. W. Robson from Montserrat, British West Indies, where some seasons it has become a menace to the peanut crop.

133. UREDO CABRERIANA Kern & Kellerm. Jour. Myc. **13**: 25. 1907.

ON FABACEAE:

Erythrina glauca Willd.

This imperfectly known rust was found in the phanerogamic herbarium of the N. Y. Bot. Garden, collected at Paso Real (Prov. Pinar del Rio), 1906, *Abarca & O'Donovan 2634*. It is known also from Porto Rico and from Guatemala, on the same host.

134. UREDO ERYTHROXYLONIS Graz. Bull. Soc. Myc. Fr. **7**: 153. 1891.

ON ERYTHROXYLONACEAE:

Erythroxylon havanense Jacq., San Antonio de los Baños (Prov. Habana), Nov. 21, 1904, *Baker 4127* (Barth. Fungi Columb. *2287*); San Diego de los Baños (Prov. Pinar del Rio), Feb. 7, 1915, *Johnston 174;* Soledad, Cienfuegos (Prov. Santa Clara), Nov. 5, 1915, *Johnston 198;* Santiago de las Vegas, Oct. 24, 1915, *Johnston 131;* Cerros de Vivijagua, Isle of Pines, Feb. 28–29, 1916, *Britton, Britton & Wilson 15023;* Taco Taco (Prov. Pinar del Rio), Sept. 17, 1916, *Johnston 878*.

This imperfectly known species was also detected on a phanerogamic collection of the same host in the N. Y. Bot. Garden, from Sierra de Anafe (Prov. Pinar del Rio), Dec. 28, 1911, *Percy Wilson 11569*. The only other station in North America for this South American rust is on Mona Island, a small island not far from Porto Rico.

135. **Uredo Saviae** sp. nov.

ON EUPHORBIACEAE:

Savia sessiliflora (Sw.) Willd., San Juan, Isle of Pines, March 15, 17, 1916, *Britton, Britton & Wilson 15453*.

Uredinia hypophyllous, scattered, oval or oblong, 0.1–0.3 mm. long, subepidermal, rather tardily naked, cinnamon-brown, ruptured epidermis usually overarching and conspicuous; peridium and paraphyses wanting; urediniospores angularly obovoid, usually triangular above, 16–20 by 23–29 μ; wall cinnamon-brown, thin, about 1 μ, closely echinulate, the pores 3, approximately equatorial, in the projecting angles.

The spores have an unusual appearance from the position of the pores in the three corners. Seen from above the spores appear triangular. They are usually narrowed and sometimes shrunken below the pores, giving a pyriform appearance from the side.

136. **Uredo Sapotae** sp. nov.

ON SAPOTACEAE:

Achras Sapota L. (*Sapota Achras* Willd.), Santiago de las Vegas, March 5, 1916, *Johnston 493* (type).

Uredinia hypophyllous, scattered or somewhat gregarious in close groups of a few each on small discolored areas, 0.5–1 mm. across, oval, 0.1–0.3 mm. long, subepidermal, rather tardily naked, cinnamon-brown, pulverulent, opening by a lateral rupture of the epidermis which remains as an evident flap; peridium and paraphyses none; urediniospores in one view triangular, when revolved one fourth broadly obovate, 18–22 by 21–26 μ; wall cinnamon-brown, moderately thick, 1.5–2 μ, closely echinulate, the pores 2, opposite and close to the hilum, in the obovoid view of the spore seen in the lateral walls.

The same fungus on the same host was collected by E. W. D. Holway at Nassau, Bahamas, March 2, 1903.

137. **Uredo Lucumae** sp. nov.

ON SAPOTACEAE:

Lucuma nervosa A. DC., Santiago de las Vegas, June 25, 1915, O, II, *146* (type), Feb. 23, 1916, II, *490*, March 5, 1916, O, II, *494*, all by *Johnston*.

Pycnia amphigenous, numerous, on discolored spots 5–15 mm. across, punctiform, honey-yellow becoming brown, subcuticular, hemispherical in section, 80–100 μ broad; ostiolar filaments wanting.

Uredinia amphigenous, rarely only hypophyllous, surrounding and among the pycnia on purplish-brown spots, usually crowded, irregularly roundish, 0.1–0.3 mm. in diameter, subepidermal, early naked, pulverulent, the hypertrophied tissues forming a protective structure for the sorus; urediniospores globoid or broadly ellipsoid, 24–35 by 35–42 μ, larger when wet by swelling of the gelatinous layer; wall lamellate, the inner portion firm, golden- or cinnamon-brown, 2–3 μ thick, the outer portion pale, swelling to 4–9 μ thick, the cuticle bearing coarse, conical tubercles, the pores indistinct.

The distinctive character of this rust suggests its relation to *Prospodium* or *Uropyxis*. The *Uromyces Lucumae* Diet., from Brazil, is a wholly unlike species, judging from the description.

138. UREDO OPERCULINAE Arth. Mycologia 9: 95. 1917.

ON CONVOLVULACEAE:

Operculina dissecta (Jacq.) House (*Convolvulus dissectus*

Jacq.), vicinity of Santiago de Cuba, Feb. 14, 1892, *Pollard & Palmer 271.*

This most unusual form of uredinia constitutes a species heretofore known only from the type collection taken in Porto Rico.

139. UREDO CEPHALANTHI Arth. Bull. Torrey Club **29**: 231. 1902.
ON RUBIACEAE:
Cephalanthus occidentalis L., Vivijagua, Isle of Pines, March 18–20, 1916, *Britton & Wilson 15609.*

Until this collection came to hand the species has only been known from the type material from southern Florida. It is an inconspicuous form, with applanate sori and no protecting structures.

140. UREDO PROXIMELLA Arth. Mycologia **7**: 324. 1915.
ON CICHORIACEAE:
Lactuca intybacea Jacq.

This rust has been found on a phanerogamic specimen in the herbarium of the N. Y. Bot. Garden, collected at Guantanamo Bay (Prov. Oriente), March 17–30, 1909, *N. L. Britton 2161.* It is also known from Porto Rico and St. Domingo. The rust appears to belong under the genus *Puccinia*, but no teliospores have yet been discovered.

INDEX TO UREDINALES

New and newly combined names are in **bold face** type

HOST INDEX

THE PHYSIOLOGICAL PROPERTIES OF TWO SPECIES OF POISONOUS MUSHROOMS*

By Michael Levine

(with plates 1 and 2)

The older literature of mushroom poisoning has been thoroughly summarized in the works of Paulet (1793), Gillot (1900), Ford (1906–7–8), Ferry (1911), Sartory (1914) and others. Within the last decade more careful experimental studies have been made by mycologists, physiologists, and physicians, which throw new light on the physiological and toxicological effects both of the older well-known poisonous forms and certain species hitherto unsuspected or unknown.

Gillot (1900) studied the physiological effects of the extracts of eight species† of mushrooms on dogs, guinea pigs, and rabbits. Various quantities (25–100 gm.) of each species were macerated with ether and filtered. The filtrate was evaporated and dried at 100° for two hours. The residue was either diluted in water and injected subcutaneously or powdered and then fed to dogs. The quantities injected varied from 3 to 5 c.c. All species caused death in guinea pigs except *Lactaria rufa*, *Cantharellus aurantiacus*, and *Hypholoma fasiculare*, which were found to be harmless.

Ford (1911), besides making his well-known chemical studies of the *Amantia* species, has also investigated haemolysins, agglutinins and toxins found in a number of other species of fungi. Aqueous extracts of the macerated pilei were studied by injecting subcutaneously in different animals a given quantity of the extract before and after boiling. He was thus able to determine the presence of thermolabile or thermostabile haemolysins, agglutinins, and toxins. Besides studying eight species of *Amanita* and

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* *From the Department of Physiology, Columbia University.*

† *Clitocybe nebularis, Cantharellus aurantiacus, Hypholoma sublateritium, H. fasiculare, Russula sanguinea, R. Queletii, Lactaria vellerea,* and *L. rufa.*

Amanitopsis volvata he investigated five species from other genera* in which he found a haemolytic substance. In three other species† of agarics he found heat-resisting haemolysins while in six species of *Entoloma*, two species of *Hypholoma*, and four species of *Boleti* he found no haemolysin. In all, thirteen species of fungi showed the presence of agglutinins which were destroyed by heating to 60–65° C. for one half hour, while eight species contained heat-resisting agglutinins which in this respect resembled the agglutinin of the fly agaric, *Amanita muscaria*, as he had earlier described it (1906, 1909). Ford has made it clear that while extracts of various poisonous mushrooms when injected subcutaneously into guinea pigs or rabbits show evidence of toxic properties and also contain haemolysins and agglutinins,‡ other poisonous mushroom juices may lack entirely or be deficient in both haemolysins and agglutinins,§ while still other species show haemolysins and agglutinins and yet are not toxic.‖ Ford maintains that herbivora are entirely non-susceptible to the action of the most virulent of the poisonous species of mushrooms when they are introduced into the stomach. Later Ford in collaboration with Sherrick (1911) investigated the toxic properties of ten species of *Boleti* and of *Clitocybe dealbata sudorifica*. They found that *Boletus felleus*, *B. miniato-olivaceus*, and *B. chromapes* have no agglutinin or haemolysin but contain some toxic substance which when injected subcutaneously into the body of the guinea pig caused chronic intoxication and finally death. This supports in the main the claim of Collins (1898) who reported a non-fatal case of mushroom poisoning due to eating *Boletus miniato-olivaceus* var. *sensibilis*. Rabbits were likewise affected by extracts of *B. felleus*. Four other species of *Boletus* (*B. affinis*, *B. ornatipes*, *B. bicolor* and *B. separans*) were found to have haemolysins or agglutinins but

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* *Clitocybe multiceps*, *Hygrophorus pratensis cinereus*, *H. pratensis albus*, *H. marginatus* and *Lactaria torminosa*.

† *Inocybe infelix*, *Galera tenera*, and *Naucoria firma*.

‡ *Amanita phalloides*, *A. muscaria*, *Lactaria torminosa*, and *Inocybe infelix*.

§ *Amanita Morrisii*, *A. spreta*, *A. citrina*, *A. crenulata*, *Amanitopsis vaginata*, *Clitocybe illudens*, *Lactaria uvida*, *Russula squalida*, *Tricholoma ustale*, *Hygrophorus pratensis cinereus*, *H. pratensis albus*, *H. hypothejus*, *H. conicus*, *Entoloma nidorosum*, *E. sinuatum*, *E. salmoneum*, *E. strictius*, *E. cuspidatum*, *E. rhodopolium*, *Hypholoma instratum*, *H. cernuum*, *Panaeolus retirugis*, and *Boletus paluster*.

‖ *Clitocybe multiceps*, *Hygrophorus parvulus*, *Flammula betulina*, *Galera tenera*, and *Naucoria firma*.

were not toxic to guinea pigs or rabbits, while *B. Ravenelii*, *B. Roxanae*, and *Strobilomyces strobilaceus* were found to have no haemolysin or agglutinin and were not toxic to any animal. Ford and Sherrick substantiated Peck's (1911) earlier report on the effect of ingesting *Clitocybe dealbata sudorifica*. Extracts of this fungus injected subcutaneously into the body of a rabbit caused excessive salivation; the animal became weak and apparently very sick, but recovery followed in twenty-four hours. A similar extract injected into the body of a guinea pig caused death within fifteen minutes. The authors conclude that the extract of *Clitocybe dealbata sudorifica* is similar in its effects to that of muscarine or the pilocarpine series. In a further paper Ford and Sherrick (1913) report an attempt to isolate the toxic substances in *Clitocybe dealbata sudorifica*, *Inocybe decepiens*, and *Pholiota autumnalis*. They found that the chemically extracted preparations of all these mushrooms were toxic to rabbits and guinea pigs.

The extracts of the American forms of *Helvella esculenta* gave negative results when injected into guinea pigs and rabbits, though the European species shows toxic properties which have been attributed to helvellic acid, as first described by Boehm and Külz (1885).

Clark and Kantor (1911) studied the effects of extracts of *Amanita muscaria*, *Inocybe infida*, and *Clitocybe multiceps* on frogs. Extracts of these mushrooms were injected into the dorsal lymph-sac of frogs or were given to them by way of the mouth. The *Amanita* extract killed a frog in from four to twenty-five minutes after injection. The *Inocybe* extract caused lethargy, paralysis, and finally death. *Clitocybe multiceps*, unlike the other species of *Clitocybe* reported by Ford and Sherrick (1911, 1913) and Gillot (1900), proved to be harmless. Clark and Smith (1913) continued further the investigations of the properties of *Amanita muscaria*, *Inocybe infida*, *Clitocybe multiceps*, and another species, *Clitocybe illudens*, on the hearts of frogs. The heart was exposed and connected with the kymograph so that a record of the normal contraction was made. The extract in physiological salt solution was next applied to the heart. In the case of the application of the extracts of the *Amanita*, *Inocybe*, and *Clitocybe illudens*, the heart slowed up and soon ceased to beat. This effect was then overcome by the application of atropine. When *Clitocybe multiceps* was applied no effect was noted. These authors hold that *Clitocybe illudens* and *Inocybe infida* contain a muscarine-like substance as had already been pointed out by Ford and Sherrick (1911, 1913). Radais and Sartory (1914), in an endeavor to determine the part of the fungus that contains the most toxin, investigated all the structures of *Volvaria gloiocephala* and *V. speciosa*. They found that the bulb and pileus contained the most poison and the stipe the least.

Murrill (1909) reported a case of poisoning due to ingestion of *Panaeolus papilionaceus* and *Inocybe infida* experienced by a physician and members of his family. The mushrooms caused a queer feeling, an increased heart action, excessive perspiration, and diarrhoea. Another member of the household was prostrated. Murrill (1916) later reported the appearance of a new toxic species in this genus which he called *Panaeolus venenosus* Murrill. The material came from commercial mushroom beds. The plants had been mistaken and eaten for *Agaricus campestris*, the commercial mushroom. The persons after eating of the plant became ill, dazed, and experienced a rapidly decreasing heart action and dilation of the pupils. A physician diagnosed the case as poisoning due to muscarine.

In studying the development of *Agaricus campestris*, I found in 1916–1917 in the mushroom beds of one of the largest mushroom growers in the region of New York City great numbers of the new fungus which Murrill had described as *Panaeolus venenosus* Murrill. These plants appeared about the same time as *Agaricus campestris* and were scattered among it; and since the spawning of the different beds was so timed as to give a constant supply of the market mushroom throughout the winter, *Panaeolus venenosus* also appeared regularly from October, 1916, to May, 1917. *Panaeolus venenosus* (PL. 1, FIGS. 1–8; PL. 2, FIGS. 9–15) is a small mushroom with a fulvous or isabelline (Ridgway) colored cap 3–5 cm. in diameter. Its stem is in length about twice the diameter of the cap and is covered with a white tomentum at its base, while its upper part is striate and covered with fine scales. The stipe is slightly darker in color than the pileus. The plants appear in fairy rings about one to two feet in diameter. Very often two or three plants grow in a cluster with the bases of their stipes united (PL. 1, FIGS. 1, 2; PL. 2, FIG. 9). The odor of this plant is like that of the commercial mushroom but the two plants could never be mistaken for each other.

I have studied the effect of infusions of this fungus (I) on guinea pigs and rabbits when injected into or fed to these animals; (II) on the heart-beat and blood-pressure of a cat; (III) on a skeletal muscle such as the gastrocnemius of the frog, and finally (IV) on the sciatic and vagus nerves of the frog.

MATERIAL

While *Panaeolus venenosus* grew rather abundantly in the mushroom beds where I made my collections, no great bulk of it could be obtained at any one time. The largest quantity I collected at any one time weighed from twenty-five to forty grams. I have as yet made no attempt to isolate the toxic element of the fungus in a pure state, but its common occurrence in commercial mushroom beds makes a knowledge of the general physiological effects highly desirable from a practical point of view. It is also of much interest to compare its physiological effects with those of the other well-known types of poisonous fungi. With two exceptions (extracts Nos. 5 and 6) I used for my experiments infusions of this plant and the different infusions listed below give some idea of the amount of material available and the relative toxicity to be expected of the plants, so far as their juices are concerned. The plants collected were brought to the laboratory where they were washed in tap water to remove the soil particles and rinsed in distilled water. They were then dried by applying filter paper to them and after that they were weighed and the juices were expressed.

Infusion No. 1 was made by macerating 25 gm. of *Panaeolus venenosus* in 25 c.c. of distilled water. The filtrate was diluted with sufficient water to make up 25 c.c. of fluid. The filtrate was yellowish orange in color at first but after standing for four hours its color changed to dark brown.

Infusion No. 2 consisted of the juices of 25 gm. of *P. venenosus* ground with sand in a mortar to which 75 c.c. of distilled water had been added. The filtrate from the entire mass was used.

The plants used in making this infusion are shown in PLATE 6, FIGURES 1–6.

Infusion No. 3 was made by grinding 13 gm. of *Panaeolus venenosus* to which sufficient water was added to make a filtrate of 50 c.c.

Infusion No. 4 was made from 25 gm. of *Agaricus campestris* treated as described for infusion No. 3. This infusion served as a control.

No. 5 was an extract made by grinding 5 gm. of *P. venenosus* which had been dried at room temperature and 45 c.c. of distilled water. The filtrate was evaporated at 25° C. giving .5 gm. of a brownish-yellow mass. This was mixed with 10 c.c. of distilled water.

Extract No. 6 was made by rubbing up the residue on the filter obtained in making extract No. 5, with absolute alcohol and filtering. The filtrate was evaporated and the mass was shaken up with 25 c.c. of distilled water.

Infusion No. 7 was made like extract No. 5, but with the exception that the filtrate was not evaporated. There were 30 c.c. of the filtrate, which was greenish yellow at first and gradually became a darker greenish yellow.

Infusion No. 8 was made by thoroughly crushing 10 gm. of fresh *P. venenosus* to which was added 40 c.c. of distilled water. This was allowed to stand for 24 hours before filtering.

Infusion No. 9 was made by rubbing 25 gm. of mature *P. venenosus* (PL. 7, FIGS. 9–15) with 25 c.c. of distilled water. The pulpy mass was allowed to stand for 24 hours before filtering. The filtrate was no further diluted but sufficient sodium chloride was added to make the solution isotonic with the muscle tissue of the turtle.

Infusion No. 10 was made of *Panaeolus retirugis* (PL. 7, FIGS. 16–19); 12 gm. of plants of this species were macerated with an equal quantity of distilled water. Sufficient sodium chloride was added to make the solution isotonic with turtle muscle tissue. The mass was filtered 24 hours after maceration. The filtrate was black in color and had the odor of crushed lawn grass (*Poa pratensis*).

Infusion No. 11 was made of a species of mushroom which resembled in all respects *P. venenosus* with the exception that it had a comparatively short stipe and no marked tomentum at the base of the stipe. This plant I shall describe later as a form of *P. venenosus*. To 15 gm. of these plants was added 15 c.c. of distilled water. The filtrate was diluted to make 20 c.c. of fluid and sufficient sodium chloride was added to make it isotonic with the muscle tissue of the turtle.

Infusion No. 12 was made of mature specimens of *P. venenosus*. 20 gm. of fresh mushrooms were macerated with 30 c.c. of .7 per cent saline solution. The liquor was permitted to stand for twenty-four hours before filtering.

Infusion No. 13 was made of 10 gm. of *P. venenosus* macerated with 10 c.c. of .8 per cent saline solution three days after the plants were collected. The infusion was filtered twenty-four hours later.

The effects of such aqueous infusions of *Panaeolus venenosus* on guinea pigs and rabbits were tested, first, by intraperitoneal injections; second, by subcutaneous injections; and third, by feeding the infusions or the fresh mushroom mixed with small pieces of lettuce to the animals. In making the injections aseptic methods were followed.

THE EFFECT OF INTRAPERITONEAL INJECTIONS ON GUINEA PIGS AND RABBITS

The results of the intraperitoneal injections are given in TABLE 1. The quantity of infusion injected varied from ½ to 2 per cent of the body weight of the animal. In some experiments (see table) the infusion was used as made. In other cases 1 c.c. of the infusion was mixed with 4 c.c. to 9 c.c. of physiological salt solution, distilled water or tap water. The results obtained by injecting the given quantities of *Panaeolus venenosus* infusion invariably caused the death of the guinea pig in about twenty-four hours. After the injection was made the animal usually was restless and moved about in an apparently dazed condition. This was followed by a period of lethargy, from which he never recovered. During this period he generally assumed a characteristic position. The head was retracted between the shoulders and the eyes were closed. When the eyes were open the animal usually appeared stupid and dazed. Noises made by

TABLE 1

EFFECT OF INTRAPERITONEAL INJECTIONS OF PANAEOLUS INFUSIONS

No.	Date	Animal*				Injection			General behavior	Respiration	Sense responses			Time of death	Autopsy		Remarks
		Kind	Wgt. in gm.	Age	Sex	Time, P. M.	Quantity in c.c.	Infusion			Sight	Hearing	Touch		Date	Findings	
1	1.16.1917	G.P.	665	Old	F.	4:05	6	1	Immediate crouching; head retracted; lethargic	Increased	Eyes closed	Not disturbed by noise	Responds to touch; startled	8:45 P.M.	1.17.1917	Hemorrhagic area in abdominal wall in region of injection; intestine distended, not injured	7:05 P.M., gave premature birth to 3 young
2	1.16.1917	G.P.	535	Old	M.	4:15	5	1	Animal in stupor, moved restlessly	Increased		Not disturbed by noise	Responds to touch; startled	3 P.M. 1.17.1917	1.17.1917	Hemorrhagic areas near pyloric end of stomach	
3	1.29.1917	G.P.	422	Old	F.	3:12	4.2	2	Retracted head;† stupefied; spasmodic motion of head. 3:50 P.M., posterior portion of body paralyzed	Markedly increased		No response to noises		9:30 A.M. 1.30.1917	1.30.1917	Hemorrhagic areas near pyloric end of stomach and along entire length of small intestine	Urine discharged before death was apparently normal
4	2.5.1917	G.P.	467	Old	F.	2:25	9.3	2	Same as no. 3; more marked; paralysis appeared early	Markedly increased				6:40 A.M. 2.6.1917	2.6.1917	No hemorrhages; vital organs normal	

* G.P. = guinea pig.

† Immediately after the injection the animal repeatedly jumped by raising its fore legs off the floor of the cage while its hind legs remained unmoved.

TABLE I

Effect of intraperitoneal injections of Panaeolus infusions (cont.)

No.	Date	Animal*				Injection			General behavior	Respiration	Sense responses			Time of death	Autopsy		Remarks
		Kind	Wgt. in gm.	Age	Sex	Time, P.M.	Quantity in c.c.	Infusion			Sight	Hearing	Touch		Date	Findings	
5	2.5.1917	G.P.	489	Old	F.	2:30	2.5	2	Dazed appearance, crouching, restless; spasmodic abdominal contraction with increasing frequency	Noticeably increased; breathing labored		No response to noises		4:10 P.M. 2.6.1917	2.6.1917	No injury to intestine as result of injection; hemorrhagic areas along intestine present	Heart stopped in diastole
6	2.12.1917	G.P.	517	Old	M.	2:50	1	2	Restless; hind legs appear affected; crouching; appears dazed		Eyes open						Animal normal after 24 hours
7	2.12.1917	G.P.	412	Young	M.	3:00	1 + 4 tap water	2	Animal became quiet after injection; stupor; hind legs paralyzed; spasmodic contraction of head and fore legs	Respiration is more rapid than normal; very rapid at times		No response to noises	Startled on being touched	5:02 P.M. 2.13.1917	2.13.1917	Hemorrhagic areas of abdominal wall when injection was given; a yellow gelatinous mass covered the inner lobes of liver	

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* G. P. = guinea pig.

TABLE I

EFFECT OF INTRAPERITONEAL INJECTIONS OF PANAEOLUS INFUSIONS (cont.)

No.	Date	Animal*				Injection			General behavior	Respiration	Sense responses			Time of death	Autopsy		Remarks
		Kind	Wgt. in gm.	Age	Sex	Time, P. M.	Quantity in c.c.	Infusion			Sight	Hearing	Touch		Date	Findings	
8	2.12.1917	G.P.	407	Young	M.	3:10	½+ 4 tap water	2	Stupor; asleep; hind legs paralyzed; 2.13.1917, lying on one side; spasmodic contraction of upper portion of body	2.13.1917. Respiration rapid, labored				4:41 P.M. 2.13.1917	2.13.1917	Hemorrhagic areas along intestinal wall	Hearing and sense of touch dull
9	3.1.1917	G.P.	389	Young	F.	3:35	4	3	Effect immediate	Respiration increased				3.2.1917	3.2.1917	No local injury; hemorrhagic areas along intestine and stomach; intestine inflated	Sense of sight and hearing dull
10	3.1.1917	G.P.	485	Old	M.	3:45	1+ 9 water	3	Quiet; does not feed; stupor	Respiration increased				3.2.1917	3.2.1917	Organs normal, but yellow patches similar to those noted in 7 appear on liver and intestine	

* G. P. = guinea pig.

TABLE I

EFFECT OF INTRAPERITONEAL INJECTIONS OF PANAEOLUS INFUSIONS(cont.)

No.	Date	Animal*				Injection			General behavior	Respiration	Sense responses			Time of death	Autopsy		Remarks
		Kind	Wgt. in gm.	Age	Sex	Time, P.M.	Quantity in c.c.	Infusion			Sight	Hearing	Touch		Date	Findings	
11	3.2.1917	G.P.	445	Old	M.	2:30	3	7	Stupor; head retracted and inactive	Respiration increased				3.22.1917	3.22.1917	Stomach and intestines inflated; whitish-yellow patches on liver	
12	5. 8.1917	R.	990	Young	M.	3:00	3 + 2 .8% saline	12	Effect immediate; stupid; dazed. 6 P.M., unable to stand; refuses food	Respiration markedly increased				5. 9.1917	5. 9.1917	No local injury; intestine distended with gas	
									Control								
1	2. 5.1917	G.P.	510	Old	M.	2:40	6 .8% saline		No ill effects noted; animal fed after injection; normal								Observation on 2.12.1917, found animal normal
2	2. 5.1917	G.P.	639	Old	M.	2:45	12 tap water		Animal appeared uncomfortable; recovery followed rapidly								Observation 2.5.1917; animal normal
3	2.12.1917	G.P.	606	Old	M.	3:25	6	4	Normal								Observation 2.19.1917; animal normal
4	2.12.1917	G.P.	290	Young	M.	3:35	5.5	4	Normal								2.19.1917; animal normal
5	2.12.1917	G.P.†	389	Young	M.	3:40	4 tap water *		Normal								2.19.1917; animal normal

* G.P. = guinea pig. R. = rabbit.

† See text, page 187.

tapping the cage failed to stimulate. It was only when the animal was caught that it showed signs of life and its efforts to resist were very futile. In a number of cases, Nos. 3 and 4, TABLE I, and others, it appeared that soon after the injection the hind portions of the body responded feebly when touched and there were spasmodic contractions of the head and fore legs. In all cases after an intraperitoneal injection was made the rate of respiration increased considerably. On approaching death there was generally a period of feeble respiratory movements, followed by rapid breathing, which often appeared labored. In all cases where death occurred an autopsy was performed, primarily to determine whether or not the injection had caused mechanical injury to the intestines or other abdominal organs. In no cases was there any trace of such injury of the intestine or stomach or any other abdominal organ. There was, however, a distension of the intestine due to gases and the pyloric end of the stomach and intestine showed hemorrhagic areas.

Injection of extract No. 6 proved to be harmless.

A number of control experiments (see TABLE I) were performed simultaneously with the *Panaeolus* tests. Tap water, .8 per cent physiological salt solution, and infusions of *Agaricus campestris* were used. As in the *Panaeolus* tests a quantity of liquid equal to 1 to 2 per cent of the body weight of the animal was injected. The animal shortly after the injection fed and appeared normal in every respect and remained so. The animal in control experiments No. 5, TABLE I, was later injected (March 1, 1917) with 4 c.c. of infusion No. 3. Immediately afterward he developed all the symptoms of *Panaeolus* intoxication and died within twenty-four hours. An autopsy failed to show any abnormality other than those described above.

The above experiments show clearly that intraperitoneal injections of *Panaeolus venenosus* prove fatal to guinea pigs and rabbits and that relatively small quantities bring about this result. The symptoms in many respects are not unlike those caused by other mushroom poisons as reported by Ford and others. The extracts of dry material give the same results as the infusions made by fresh plants; both are equally toxic.

THE EFFECT OF A SUBCUTANEOUS INJECTION OF PANAEOLUS VENENOSUS

Different quantities of *Panaeolus venenosus* infusion were injected subcutaneously into guinea pigs and rabbits. In all twelve tests were made and TABLE 2 gives the results of some of the more interesting ones. The early symptoms noted for intraperitoneal injections appeared in these experiments but the effects were not so pronounced. There was the lethargic state, during which the animal did not feed and responded very poorly to external stimuli. These effects, however, wore off more or less quickly; the time of recovery varying with the individual animals. The sensory responses became normal within 48 hours in the most poisoned animals. In all injected animals there was evidence of continued local irritation lasting a number of days after the injection. The animal persistently licked the skin where the injection was given. About a week after the injection, the skin in the region of the wound broke down and a lesion was formed covering an area of 3 to 4 cm. This sloughing off of the skin invariably occurred when a subcutaneous injection was given. The skin healed completely three to four weeks later. No death occurred as a result of a subcutaneous injection.

It appears from the experiments that, unlike the intraperitoneal injections, the subcutaneous injection of *Panaeolus venenosus* in the quantities employed does not produce fatal results. However, temporary intoxication results and a sloughing off of the skin in the region of injection is sure to follow in both guinea pigs and rabbits. In this respect *Panaeolus venenosus* infusion behaves like the extract of *Clitocybe multiceps* reported by Ford (1911). Small quantities of the *Panaeolus venenosus* infusion are sufficient so to affect the skin (see experiment No. 3—TABLE 2).

THE EFFECTS OF FEEDING PANAEOLUS VENENOSUS TO GUINEA PIGS

Guinea pigs refuse the fresh pilei, but when these are crushed and mixed with lettuce leaves they will eat small quantities. When fed lightly with their customary food for twenty-four hours previously they take the *Panaeolus* more readily. In this way it was possible to feed them 5 gm. of the plants at one time. In-

TABLE 2

EFFECT OF SUBCUTANEOUS INJECTIONS OF PANAEOLUS INFUSIONS

o.	Date	Animal*				Injection			General behavior	Respiration	Sense responses			Remarks
		Kind	Wgt. in gm.	Age	Sex	Time, P.M.	Quantity in c.c.	Infusion			Sight	Hearing	Touch	
1	1.22.1917	G.P.	345	Young	M.	3:40	7	1	Quiet after injection; head retracted; restless; refuses food; stupor; does not resist handling	Increased	Eyes closed	Dull	Responds feebly when touched	1.23.1917, animal partly recovered from stupor 1.29.1917, lesion of skin in region of inoculation 2.12.1917, animal normal; wound healed
2	3.8.1917	G.P.	385	Young	F.	3:20	1 + 5 tap water	5	Animal appeared disturbed after injection; recovery followed; ate greedily	No effect		Alert		3.25.1917, large area of skin in region of injection peeled off; tissue below bleeding 3.29.1917, wound healing; animal normal
3	3.15.1917	G.P.	339	Old	F.	3:15	1 + 7 .8% saline	3	Recovery shortly after injection	No effect	No effect	No effect		3.20.1917, lesion of skin as in cases above
4	5.3.1917	R.	1,135	Young	M.	3:10	5	12	Stupid; in lethargy; refused food 5.4.1917, condition improved; feeds 5.7.1917, completely recovered from state of lethargy	Respiration increased, but effects soon wore off	Dull	Dull	Is startled when touched	5.5.1917, skin in region of injection moist, due to biting 5.8.1917, lesion of skin in region of injection 5.28.1917, skin healed

*G. P. = guinea pig. R. = rabbit.

fusions of *Panaeolus venenosus* were also administered by way of mouth by means of a medicine dropper. In all, four experiments are recorded in TABLE 3. The results show that these fungi fed to guinea pigs will make the animal stupid and appear dazed but recovery follows in an hour or two. Feeding of the infusion to guinea pigs gave uniform results except in one case, No. 4, recorded in TABLE 3. In all, eight such experiments were made with infusions Nos. 2 and 3 and extract No. 5. None, however, caused death. The guinea pig in experiment No. 4 (TABLE 3) behaved after the feeding as if it had been injected intraperitoneally and died five hours after feeding. The autopsy showed hemorrhagic areas along the intestinal wall and at the pyloric end of the stomach. It is possible that this animal died of pneumonia. It is quite likely that some of the fluid may have gone into the lungs.

It appears from these experiments that feeding of *Panaeolus venenosus* at least causes temporary intoxication with increased respiration, but recovery follows within several hours. It has been claimed by Ford (1911) that herbivora are not susceptible to mushroom toxins when given to them by way of the mouth.

The effect of an intravenous injection of an infusion of *Panaeolus venenosus* was tried on rabbits. Small quantities, 2 c.c. of a mixture of 1 c.c. of infusion No. 12 and 20 c.c. of .8 per cent physiological salt solution, were injected into the marginal vein of the right ear. The rate of respiration began to increase shortly after the injection until the breathing became labored. The animal became deeply intoxicated and its senses dulled; all food offered after the injection was refused. Although he began to feed on the following day, this intoxicated condition lasted for three days, when the effect of the injection began to disappear. Nine days later the animal appeared normal. Two further experiments were made in which 2 c.c. of solution No. 13 were injected intravenously. Neither proved fatal, although severe intoxication was induced, which lasted four to five days, during which time the symptoms described above were observed. It is quite likely that with larger doses of the infusion No. 13 the results would be fatal.

TABLE 3

EFFECT OF FEEDING PANAEOLUS

No.	Date	Animal				Food		General behavior	Sense responses			Time of death	Autopsy		Remarks
		Kind	Wgt. in gm.	Age	Sex	Kind	Quantity		Sight	Hearing	Touch		Date	Finding	
1	1.29.1917	G.P.	430	Young	F.	Young *P. venenosus* and lettuce leaves chopped	Amount of *P. venenosus* eaten, 1 gm.	Stupefied		Dull	Must be touched to be aroused				Animal recovered after 1 hour
2	4.11.1917	G.P.	250	Young	M.	Old and young *P. venenosus* and lettuce leaves	5 gm.	Stupefied		Dull	Must be touched to be aroused				Recovery followed after 2½ hours
3	4.11.1917	G.P.	307	Young	F.	Old and young *P. venenosus* and lettuce leaves	5 gm.	Stupefied		Dull	Must be touched to be aroused				Recovery followed after 1 hour
4	2.19.1917	G.P.	475	Old	M.	*Infusion no. 2 + tap water	4 c.c. 4 c.c.	Animal appeared sick after feeding; inactive; paralysis of hind legs	Eyes closed	Unaffected by noises		5 hours after feeding	2.20.1917	Hemorrhagic areas along intestinal wall	Rate of respiration above normal, then irregular

* Food administered by medicine dropper; animal coughed during feeding.

THE EFFECT OF PANAEOLUS INFUSION ON MUSCLE

The effect of an infusion of *Panaeolus venenosus* and of *P. retirugis* was tested on the gastrocnemius muscles of the frog. Animals weighing 30–45 gm. were used in these experiments. The muscles were excised so that the skin covering was left around the muscle to prevent drying out and at the same time to form a sac into which the fluids, the effects of which were to be studied, could be placed. The method is as follows. The skin around the tendon of Achilles was cut. It was then rolled back over the gastrocnemius muscle to the knee, the tendon was severed, the muscle was carefully lifted away from the tibia and the latter was cut off near the knee. The skin was then redrawn over the muscle and the cut end of the skin was tied to the tendon so that a considerable part of it protruded below the skin. The femur was cut off near the hip, leaving the gastrocnemius attached to it. The protruding tendon was used as a point of attachment for one electrode and the femur for the other. Both gastrocnemius muscles were similarly excised. One skin sac was filled with .6 per cent physiological saline which served as a control, the other was filled with the mushroom infusion. The muscles were then suspended in moist-air chambers as an extra precaution and were attached to writing levers. The muscles were simultaneously stimulated electrically at intervals of two seconds by single induction shocks and the contractions were recorded on a slowly moving drum. The experiments were continued until the muscles were completely exhausted. Calculations were then made of the duration of the power to contract, the total number of contractions, and the total amount of work that was performed. The right and left muscles were used alternately for the *Panaeolus* infusion.

Ten experiments were performed, from which it appears clearly that *Panaeolus* infusion hastens fatigue and reduces the working capacity of the muscle. The total number of contractions of which the muscle was capable was reduced by 51 per cent and the total amount of work by 55 per cent. The length of time the treated muscle was capable of working was reduced by 51 per cent. The length of time, the total number of contractions, and the amount of work done by the normal muscles were each represented by 100 per cent. A case of extreme difference between the normal muscle and the one injected with *Panaeolus* infusion when compared with respect to the length of time the muscles were able to work before fatigue set in is shown in experiment 2 (TABLE 4). Here the normal muscle worked for a period of 28.9 minutes, while the injected gastrocnemius worked only 5.31 minutes. The total number of contractions was greater for the normal muscles than the injected ones and the greatest difference between them was observed in experiment No. 6 (TABLE 4). In all cases, without an exception, the amount of work done by the normal muscle was greater. These experiments show conclusively that the infusion of *Panaeolus venenosus* has a harmful effect on the working power of a muscle.

TABLE 4

ACTION OF PANAEOLUS INFUSIONS ON MUSCLE

NORMAL: 1–2 c.c. of .6 per cent NaCl injected into skin sac around gastrocnemius muscle.

Panaeolus EXTRACT: 1–2 c.c. of various *Panaeolus* infusions injected into skin sac around gastrocnemius muscle.

Expt.	Muscle	Dur. of work, min.	Total no. of contractions	Amount of work done, in gm.m.	Infus.	Dur. of work, min.	Total no. of contractions	Amount of work done, in gm.m.
1	R.	30.15	689.83	15.67	9	9.21	210.72	2.09
2	L.	28.9	610.08	14.22	9	5.31	112.09	.605
3	R.	29.68	695.59	17.78	9	12.81	300.26	5.28
4	L.	47.5	1134.3	25.41	10	28.9	690.13	18.91
5	R.	35.01	828.3	17.52	11	18.75	443.6	9.58
6	L.	47.18	1110.71	18.70	11	17.96	419.0	8.078
7	R.	24.53	569.59	14.878	12	11.09	257.5	3.17
8	L.	27.9	681.59	15.81	12	22.18	541.85	11.85
9	R.	32.9	745.5	18.73	12	15.15	343.29	7.63
10	L.	30.7	719.3	10.645	12	22.6	528.8	10.44
Average		32.445	778.479	16.9363		16.396	384.724	7.7633
Per cent		100%	100%	100%		49%	49%	45%

THE EFFECTS OF PANAEOLUS INFUSION ON BLOOD PRESSURE AND PULSE

Infusions of *Panaeolus venenosus* and *P. retirugis* were injected into the venous circulation of a cat to determine the effect of the infusion of these fungi on the blood pressure and pulse. A large female cat (weight 1,550 gm.) was used. She was anaesthetized with ether and after tracheotomy had been performed a mercury manometer was connected with the carotid artery. After the blood pressure was recorded on a kymograph the right femoral vein was exposed and 1 c.c. of infusion No. 9 (*P. venenosus*) diluted with 4 c.c. of .8 per cent saline solution was injected with a hypodermic needle. The fluid was allowed to flow into the vein by force of gravity. Shortly after the injection there was a slight increase of the blood pressure approximating 2 mm. which lasted three minutes and then became normal. The number of heart-beats prior to the injection was 131 per minute, and in less than a minute after the injection the heart-beat increased to 165. Fifteen minutes later 5 c.c. of infusion No. 11 (*P. venenosus*) was injected into the same vein in the same way as described above. The injection was followed by a gradual increase until a pressure of 2 mm. above normal was recorded. The pulse rate remained unchanged. Twenty-two minutes later (3:00 P.M.) 5 c.c. of infusion No. 10 (*P. retirugis*) was injected into the left femoral vein and in three seconds the blood pressure dropped gradually 14.5 mm. below the normal and then slowly increased to 11 mm. above the normal, from which point it slowly diminished until a point below the normal was attained from which there were but slight deviations. The pulse rate immediately before the injection was 144 per minute and after the injection increased to 165–170. At 3:09 P.M. another injection of 5 c.c. of infusion No. 10 (*P. retirugis*) was given through the same vein. This time there was only a decrease in the blood pressure and as in the preceding cases this was followed by an increase which was very slight in proportion to the decrease. The return to normal required a little over 10 minutes. This experiment was followed at 3:17 P.M. by an injection of 3 c.c. of infusion No. 11 (*P. venenosus*), and a record was obtained similar to that of the preceding case. The pulse rate was 169 per minute. Six minutes later an injection of 3 c.c. of .8 per cent physiological salt solution was introduced through the same vein. No change in the blood pressure or in the pulse rate occurred. After the first injection it was noted that there was a gradual decline in the blood pressure. The rate of respiration was not increased and a uniform count of 19 per minute was made. These results do not agree with those described above for rabbit and guinea pigs.

It is quite evident that infusions of *P. venenosus* and *P. retirugis* have a distinct effect on the blood pressure of a cat. Whether the decrease and increase is due to localized or general dilatation or constriction of the blood vessels, I did not attempt to determine. It is evident, however, that the changes in the blood pressure are not due to the heart-beat. As far as my experiments go, they tend to show that the heart-beat is accelerated by *Panaeolus* infusion in small quantities and this effect is quite lasting. The acceleration may be due to the paralysis of the vagus terminations, as later experiments tend to show. As noted below, applications of *Panaeolus* infusions to exposed hearts of frogs and turtles show no effect. In this respect the infusions I have used are like cocaine (Mosso, 1887, 1890) and nicotine, coniine, and piperidine (Moore and Row, 1898).

THE EFFECT OF PANAEOLUS INFUSION ON MOTOR NERVES

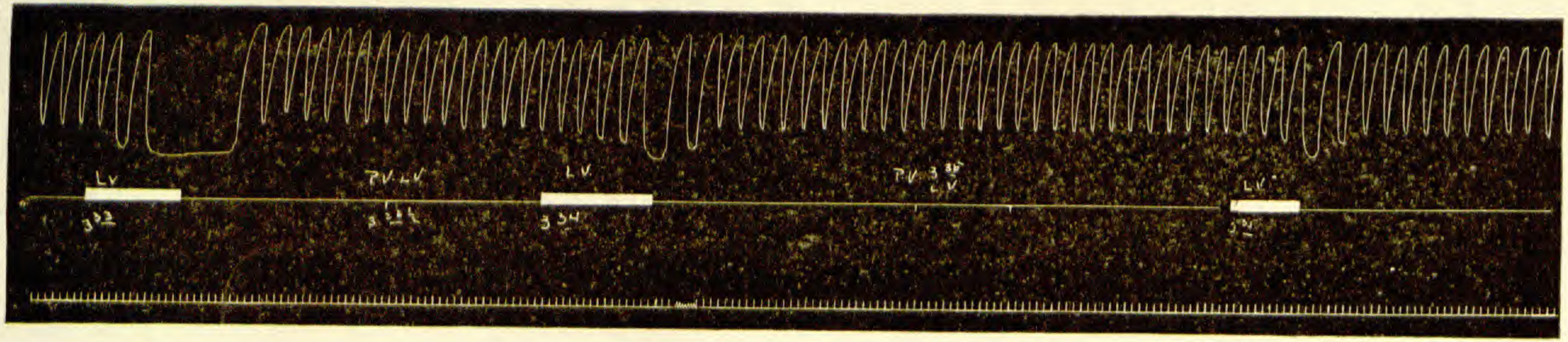
In these experiments the sciatic nerve and the gastrocnemius muscle of frogs weighing 45–50 gm. were used. The muscle was excised in the manner described above so that the skin was left as a covering about it. The muscle was then attached to a writing lever and the sciatic nerve was stretched over two pairs of electrodes thoroughly protected from currents of air. Single induction shocks were used to stimulate the nerve. After a number of normal contractions of the gastrocnemius muscle were recorded by stimulating the nerve, infusion No. 13 (*P. venenosus*) was applied to the central end of the nerve by means of a camel's-hair brush. Immediately after this the nerve was stimulated and normal contractions of the gastrocnemius muscle were obtained. After 5 to 10 applications of the extract to the nerve in a period of 3 to 5 minutes, stimulating by the make shock failed to produce a contraction of the muscle and the effects of the break shock became less and finally disappeared. On stimulating the nerve through the peripheral electrodes normal contractions were obtained by both make and break shocks. Moving the central electrode successively from its original place to ¼, ½, and ¾ of the distance between it and the peripheral electrode and stimulating the curve at each point gave in each case normal contractions of the muscle, while stimulating the nerve centrally to the first central point gave no reaction.

Applying *Panaeolus* infusion successively at 4 or 5 points between the original central and peripheral electrodes showed that the infusion had to be applied more often and for a longer period before electrical stimulation of the nerve failed to produce a muscular response and the infusion had very little effect when applied to the nerve 5 to 8 mm. from the muscle. These observations were repeated many times and in all cases application of *P. venenosus* infusion to the cut end was more effective than on the muscle end of the nerve. A .3 per cent isotonic solution of cocaine applied to the sciatic nerve and gastrocnemius muscle preparation gave me in the main similar results to that obtained with *Panaeolus* infusion. The effects of cocaine observed here are like the results obtained by Mosso (1890) in his work on the effect of cocaine on motor nerves, although Mosso's method of experimentation was different from mine. The interesting fact is that *Panaeolus* infusions showed the local paralyzing effects so well known for cocaine.

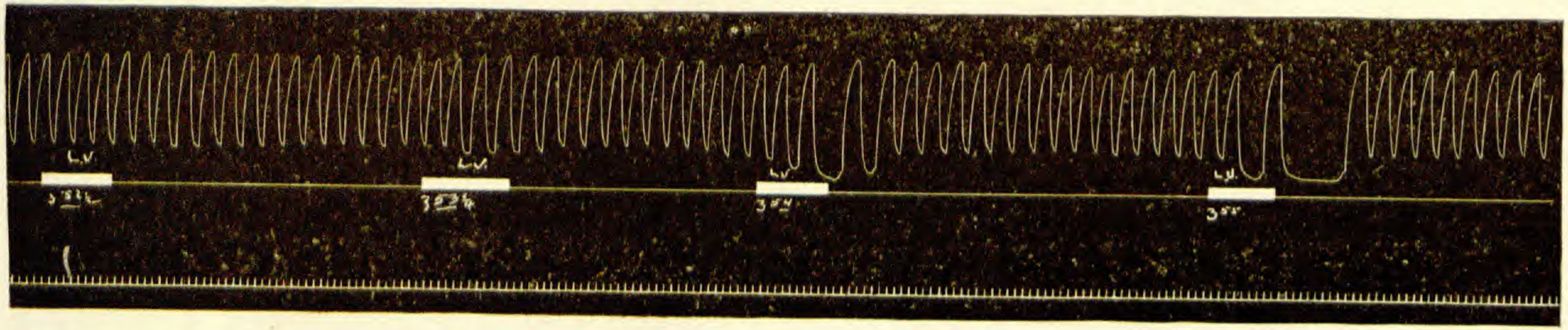
THE EFFECT OF PANAEOLUS INFUSIONS ON THE HEART AND VAGUS NERVES

The increased rate of heart-beat noted in injection of *Panaeolus* infusions into the circulation of the cat led to the investigation of the effect of this infusion on the heart and vagus nerves of the frog and the turtle. Preliminary experiments were made on frogs. After pithing the animals the two vagus nerves were exposed, and electrodes were attached. Each nerve was tested for its power to inhibit the heart-action. The apex of the heart was attached to a writing lever and the contractions were recorded on a slowly revolving drum. After normal and complete inhibition on stimulating each nerve had been recorded, a *Panaeolus* infusion was painted on the right vagus with a camel's-hair brush at a point between the electrodes and the heart. No effects on the heart were noticed and after 30 seconds the vagus was stimulated with the electric current. The heart-beat instead of stopping became slower than usual and the contraction became greater. After three to four minutes electrical stimulation produced no effect even on the rate of the heart-beat (see GRAPHS Nos. 1 and 2). Later the effects of the *Panaeolus* infusion slowly disappeared and

GRAPH NO. 1.



GRAPH NO. 2.



NOS. 1 AND 2. L. V. indicates the application of an electrical stimulus to the left vagus P. V. L. V. indicates the application of an infusion of *Panaeolus venenosus* to the left vagus. The time curve indicates seconds.

No. 1. The upper curve is a record of the contraction of a heart of a turtle showing the effect of *P. venenosus* on the left vagus nerve. Stimulation of the nerve produces no inhibition of the action of the heart.

No. 2. Continuation of the same record showing complete failure of the left vagus to cause inhibition and the recovery of the vagus 18 minutes after the administration of the infusion.

the inhibiting power of the nerve was regained. When the *Panaeolus* infusion was painted directly on the heart the contractions were in no way affected but the inhibiting function of both vagi was abolished. If the electrodes were then applied to the sinus there were the usual accelerated contractions followed by inhibition. Repeated application of the *Panaeolus* infusion to the heart of the turtle followed by stimulation of the sinus gave stronger contractions than the normal followed by inhibition. The effects of infusions Nos. 9, 10, and 12 were studied on turtles. With each infusion similar experiments were performed. It was found, however, that infusion No. 9 abolished the inhibiting action of the vagus more quickly than No. 12, and that No. 10 (*P. retirugis*) was more effective than Nos. 9 or 12. It was further observed that the complete failure of the vagus nerve to cause inhibition differed with the different turtles used, although the infusions were applied in the same manner and with equal frequency. The rapidity of recovery of the vagus nerves from the *Panaeolus* infusions to a great extent depended upon the animal.

Tests were made to determine the extent of the influence the infusion had on the nerve. The normal heart inhibitions were recorded on stimulating the vagi; then, as in the case of the frog, one of the nerves was painted with *Panaeolus* infusion at a point between the electrodes and the heart. The nerve was stimulated electrically at intervals of one minute. When stimulation failed to produce inhibition the electrodes were moved to a point between the heart and the point of application of the infusion. In all cases stimulating at the new point caused inhibition. From such experiments, I am of the opinion that the *Panaeolus* infusion acts only locally. Painting the heart of the turtle with infusion abolished the vagus action.

The similarity in the behavior of *Panaeolus* infusion to cocaine made it desirable to compare the two substances on the vagus of the same animal. After recording heart inhibitions from the right and the left vagus the former were painted with infusion No. 9, and the latter with .3 per cent cocaine. The results obtained were identical. With cocaine, however, the effect was more rapid and the recovery more slow than for *Panaeolus* infusion, although it must be borne in mind that the amount of the active element in my infusion is entirely unknown. While no chemical study of the active principle of *Panaeolus venenosus* or *P. retirugis* has been made, it appears from these experiments that they contain some substance which has a temporary and local anaesthetic effect on nerve tissue, especially the vagus nerves, and in this respect is like cocaine. Furthermore, these experiments show that *P. venenosus* and *P. retirugis* contain a substance or substances with similar physiological and toxicological properties. The most interesting fact about the infusions from these species is that they differ entirely from the extracts made of other fungi so far investigated. According to Ford and Clark and their collaborators, *Amanita muscaria*, the poisonous Russulas, Clitocybes, Inocybes, Boleti and other species of poisonous mushrooms contain a toxic substance which physiologically acts like muscarine, *i. e.*, when the extracts of these mushrooms are applied to the vagus nerve, the nerve-endings are stimulated and cause in turn the inhibition of heart-action. The infusions of *Panaeolus* species studied here show no effect on the hearts of the frogs or turtles except to anaesthetize the part of the nerve to which they are applied.

SUMMARY

1. No attempt was made to isolate the toxic substances in *Panaeolus venenosus* and *P. retirugis*. Infusions of the mushrooms were used in testing their toxic properties.

2. Infusions made by macerating *P. venenosus* with an equal weight of water produced death of guinea pigs and rabbits when ½ to 2 per cent of their body weight of the infusion was injected intraperitoneally.

3. Subcutaneous injections of these infusions into guinea pigs and rabbits caused milder symptoms than those observed in animals injected intraperitoneally; these injections did not cause death, but without exception caused the sloughing off of the skin in the region of the injection.

4. Intravenous injections of relatively small quantities of infusion into the circulatory system of the rabbit caused symptoms similar to those observed when the animal was injected intraperitoneally, but no death was recorded and the animals recovered completely within a few hours.

5. Infusions injected into the circulatory system of the anaesthetized cat produced a decrease in blood pressure followed by an increase in blood pressure, from which condition recovery followed. The rate of the heart-beat was increased.

6. Immersion of the gastrocnemius muscle of the frog in infusions caused the muscle to fatigue sooner than the normal muscle, and its working capacity was markedly reduced.

7. Application of the infusions to the cut end of the sciatic nerve of the frog affected the nerve so that its electrical stimulation failed to produce a contraction of the gastrocnemius muscle. In this respect the infusion acts like cocaine.

8. Application of the infusions to the vagus nerves of the frog and turtle affected the nerves at the point of application so that electrical stimulation at that point failed to cause heart inhibition. Painting the heart with infusion appeared to have no effect on the heart-beat but paralyzed the vagus-nerve terminations. The action of the infusion in this differs from the extracts of all other fungi so far investigated.

To Professor Frederic S. Lee and Professor R. A. Harper I wish to extend my thanks for many helpful suggestions and criticisms.

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1–8. PANAEOLUS VENENOSUS MURRILL
16–19. PANAEOLUS RETIRUGIS FR.

9–15. PANAEOLUS VENENOSUS Murrill

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EXPLANATION OF PLATES 1 AND 2

PLATE 1

FIGS. 1–8. *Panaeolus venenosus* Murrill.

FIGS. 16–19. *Panaeolus retirugis* Fr.

PLATE 2

FIGS. 9–15. *Panaeolus venenosus* Murrill.

LIFE-HISTORY STUDIES IN SCLEROTINIA

By F. J. Seaver and W. T. Horne

New York Botanical Garden *University of California*

(with plate 3)

For several years past a species of *Sclerotinia* has been observed by the writer in a certain stretch of woods in the upper end of Van Cortlandt Park, New York City, on the rootstocks of wild geranium. Although this has been seen abundantly in this particular region, it has not been detected by us in other localities where the wild geranium grows. The apothecia usually appear early in the spring about the latter part of April or early in May and disappear early in June. A search of the records showed no species of *Sclerotinia* listed for this host, so that the writer was uncertain whether this represented an undescribed species or some old species on a new host. It did not appear, however, to agree well with any described species, and it was finally decided to publish it in order to bring it to the attention of mycologists. Before doing this it was thought advisable to locate the conidial stage, if possible, in order to make the description more complete, and during the spring of 1917 this work was undertaken.

From our knowledge of other species of *Sclerotinia*, it was thought that the conidial stage might be located as a parasite on the leaves or other living tissue of the host. A careful search of the region in which the fungus occurred on various occasions showed nothing on the living plants which could be suspected of being the conidial stage of this fungus. A collection of infected rootstocks, however, which had been brought into the laboratory and placed in a moist chamber after a few days showed a most luxuriant growth of a species of *Botrytis*. This appeared in dense tufts not only on the rootstocks and rootlets, but even covered over the outside of the apothecia like a coat of fur. While none of the *Botrytis* was apparent on the plants when brought into the laboratory, it invariably appeared within a few days on the roots and rootstocks of those plants infected with *Sclerotinia*, while similar rootstocks from regions where the *Sclerotinia* was absent failed in every case to develop this type of *Botrytis*. The conidiophores often appeared in dense tufts, these often springing from minute black sclerotium-like bodies, although the latter were not always evident. Thinking that this fungus might be an omnivorous saprophyte, the rootstocks of other kinds of plants from the same region were placed in moist chambers, but failed to produce this fungus. From these rough observations it was suspected that the *Botrytis* might have some connection with the *Sclerotinia*.

It was noted that the ascospores were always in excellent germinating condition when brought into the laboratory, and it was decided to attempt to culture out the fungus. One of us (Horne), who happened to be working at the New York Botanical Garden at this time, kindly offered to culture the fungus and the following experiments were conducted by him.

CULTURE EXPERIMENTS

Crude cultures were made by touching the tufts of *Botrytis* spores, as shown in the accompanying plate, on the small roots of wild geranium with a sterile needle and then bringing the needle into contact with an autoclaved potato plug placed in a test tube. A vigorous fungus grew promptly, developing in somewhat the same way as *Botrytis vulgaris*, but readily distinguished from that species on detailed examination. A few days later a crude culture was made by touching the top of an apothecium of the *Sclerotinia* of wild geranium with a sterile needle and with this inoculating a drop of sterile water on a sterilized slide. The *Sclerotinia* spores were abundant and no *Botrytis* spores were observed in the drop on examination with the 16 mm. objective. A transfer was made from this drop to a potato plug, as with the *Botrytis* inoculation. After somewhat more than one week, these cultures were examined and both were producing the characteristic *Botrytis* spores and microconidia.

On May 20, pure cultures of the *Sclerotinia* of wild geranium were made as follows: a dried herbarium specimen of the *Sclerotinia* collected in Van Cortlandt Park during the present season was moistened by placing a small drop of sterilized water on the upper surface, using a loop needle and sometimes slightly rubbing the surface of the hymenium with the loop. Some of the material was then transferred to a drop of sterile water on a sterilized slide. Poured plate cultures were made in the usual way, being inoculated directly from the drop prepared on the slide, using prune-juice agar and Shear's cornmeal agar. Before making the poured plates, the drop used for inoculation was carefully inspected with the 16 mm. objective and no *Botrytis* spores were seen in it, in fact no spores were observed except those of the *Sclerotinia*.

After about twenty hours the agar plates were inverted and a number of germinating spores were marked. Only the colonies of mycelium clearly arising from one spore and well separated were marked. While the original spore had become considerably swollen and not recognizable with absolute certainty in some cases, it appeared from the figure of the mycelium that the *Sclerotinia* spore had given rise to the growth in every case marked. Later in the same day five of these colonies were transferred to slant tubes of prune agar. The following day six more plantings were made from separate colonies growing from marked single ascopores. By this time the colonies had become very complex and were plainly visible. Three days from the making of the poured plates the colonies were confluent and vigorous and the characteristic *Botrytis* spores had commenced to be formed. Apparently all of the colonies originating from the ascospores gave rise to the *Botrytis* spores and there were no contaminations, all of the colonies being of the same sort.

Of the single-spore transfers to prune-juice agar, three of those made on the first day failed to grow, presumably the young mycelium had been caught on the needle used in the transfer, since some had not been found on the slant after making the transfer. The remaining eight single-spore cultures developed very uniformly and all produced abundant *Botrytis* spores.

On June 24, plantings were made from each of the eight pure cultures on prune-agar slants to sterilized geranium rootstocks and to sterilized potato plugs. On the potato plugs the growth was identical with that originally secured from crude plantings of the spores of *Botrytis* and *Sclerotinia*. After four days, *Botrytis* spores could be seen with a lens in nearly all of the cultures and yellowish sclerotia were beginning to form on some of the geranium rootstocks, but no distinct sclerotia were observed on any of these or older potato cultures. Although *Botrytis* spores appeared in all of these, they were much more abundant on the rootstocks than on the potato plugs. On the rootstocks the spores were so abundant as to be evident to the naked eye, and the masses were very similar to those obtained on infected rootstocks brought from the field and placed in moist chambers, as shown in the accompanying plate. Check experiments were kept and these failed to show any evidence of the *Botrytis*.

The infected rootstocks will be kept with the hope of securing mature apothecia, but these will probably not appear until spring, as is the case in nature, and it is too soon to predict what the result of this study will be. However, the production of *Botrytis* directly from the ascospores of the *Sclerotinia* confirms field observations on the connection of the two fungi. The production of apothecia would add still more interest to the investigation.

Sclerotinia (**Stromatinia**) **Geranii** sp. nov.

Conidial stage (*Botrytis*) occurring on the roots and rootlets of the host, being especially abundant when left in moist chamber for a few days and even developing on the outside of the apothecia, usually appearing in tufts and often springing from minute sclerotium-like bodies, although the latter are not always present, dark brown in mass at maturity; conidiophores reaching a length of 1 mm. or more and a diameter of 10–15 μ, pale brown, sparingly septate and branched, the conidia borne in rather large masses like bunches of grapes; conidia subglobose or pyriform, the small end representing the point of attachment, reaching a diameter of 10 μ or rarely as large as 12 μ, slightly longer than broad, at first smooth, becoming quite strongly roughened, pale brown with transmitted light.

Apothecia springing from the partially decayed rootstocks in clusters of variable numbers, stipitate, shallow-cupshaped or subdiscoid, reaching a diameter of 1 cm. or rarely larger, pale-brown externally; hymenium concave or nearly plane, a little darker than the outside of the apothecium; stem reaching a diameter of 2 mm. and often reaching a length of several cm., though often short and occasionally almost wanting, the length varying with the depth to which the rootstocks of the host are buried; asci cylindric or subcylindric, 8-spored, reaching a length of 120–140 μ and a diameter of 8–10 μ; ascospores hyaline, ellipsoid or almond-shaped, 4–5 μ × 12 μ, usually containing two very small oil-drops. [PLATE 3.]

On the rootstocks of wild geranium (*Geranium maculatum*). The type collected in woods in the upper end of Van Cortlandt Park, New York City, May, 1917.

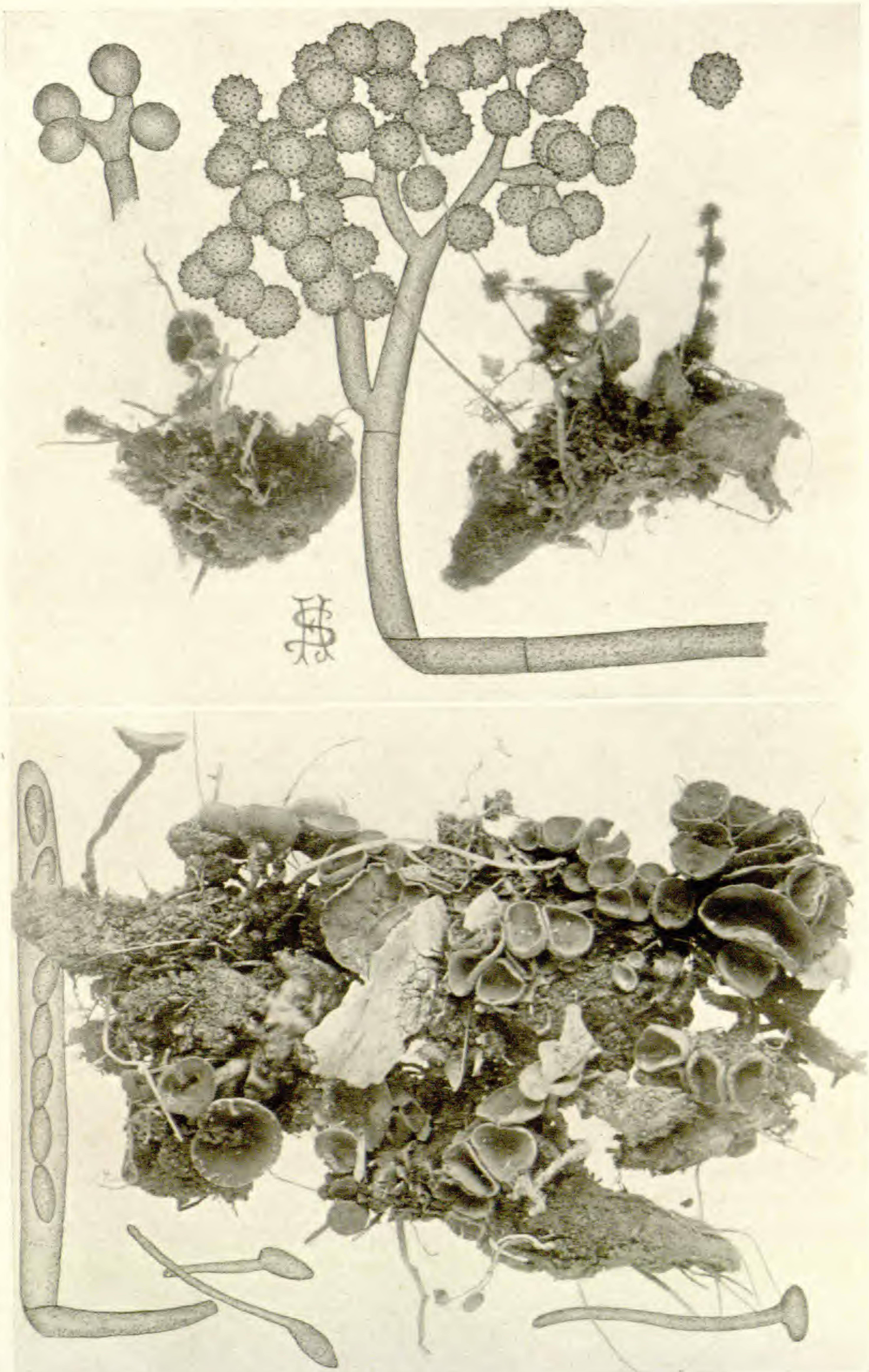
The subgenus *Stromatinia* has been raised to the rank of a genus by Boudier, although it is not commonly regarded as such. If the genus *Stromatinia* is considered distinct from *Sclerotinia* our plant would be designated as **Stromatinia Geranii.**

DESCRIPTION OF PLATE 3

FIG. 1. Photographs of the *Botrytis* stage on the underground parts of wild geranium, natural size, with drawings of sporophores and conidia enlarged.

FIG. 2. Photograph of apothecia, natural size, with drawing of ascus with spores and germinating ascospores, enlarged.

All drawings made with the aid of the camera lucida to a common scale using a one-inch eye-piece and a one-sixth objective.



SEAVER AND HORNE: STUDIES IN SCLEROTINIA

THE INDIVIDUALITY OF THE BEAN POD AS COMPARED WITH THAT OF THE BEAN PLANT

By Helene M. Boas

The New York Botanical Garden

This paper is a preliminary report on some experiments bearing on the question to what extent parts of a plant, apparently alike, may possess an individuality similar to that of individual plants.

It is a well-known fact that organs that are homologous may be differentiated from one another. For example, the first pair of leaves of the bean are, as a rule, simple, those following are compound. The foliage leaves of reproductive parts are commonly different in shape, size, and other characters from those of vegetative parts. In the composites the outer flowers of a head may be of quite a different type from the inner and often the fruits produced by them are morphologically distinct.

Many instances could be cited in which lateral organs have been found to differ from terminal organs in the number or shape of their parts. It will be sufficient here to mention the fact that the number of flowers in the inflorescences of Compositae and Umbelliferae, and the number of stamens and carpels and other floral parts in other forms, have been found to exhibit differences according to their position on the plant. Flowers have been found to differ in size, whether produced early or late in the season; as, for example, in tobacco, and in the composites it is a common observation that flower number of the heads decreases with the advance of the season.

Often, however, the differentiations are not of sufficient magnitude to be readily detected and we are then inclined to speak of variations. In such instances a detailed study frequently shows organs apparently alike to be different. The differences may be slight, but regular and significant. In other words, homologous parts may show individuality, comparable to the individuality shown by entire plants.

In the winter of 1915 an experiment bearing on this point was planned and the data recorded are from thirty-eight plants of the Longfellow variety of string-bean grown in the summer of 1916. The plants had 736 pods and 3,462 beans. The individuality of the bean pod and of the bean plant chosen for expression is the shape of the beans. An index, the thickness of the bean divided by the width measured from the hilum to the opposite side, has been used not because any particular importance is to be attached to this measure, but because it was convenient. An index of this sort is preferable to weight or to a single measurement as thickness or length because purely physiological differences due to nutrition are more probably eliminated. It was observed that the beans varied considerably in form, some being flat and others much thicker. This is expressed in the index, which varies from about 70 to about 110.

If all the pods on a plant were alike and the variations among the individual beans of a plant purely chance variations, the average index of each pod, assuming each pod to contain a large number of beans, would be the same as the average index for the plant as a whole. There would then be no variation among the pods or, in other words, they would all be alike. If, however, there are differences among the averages for the pods, the pods show individuality.

We have first to consider in how far the plants are alike or different. As we might expect, the average index is not the same for all plants. It ranges from 86 to 98, the average being 94 with a standard deviation of ± 3.4. In other words, the plants are not all alike, but have individuality, some with thicker and others with flatter beans.

We may treat the separate pods on a plant in the same way. The fact that the pods contain a small number of beans and not all pods the same number must be taken into account in the calculation, in order that the results obtained may be comparable. If the variability of the individual beans on a plant is expressed by σ, the correlation between the beans in a pod by r, and the number of beans in a pod by n; then s, the observed variability of the beans in a pod, is expressed by the following formula:

$$s^2 = \frac{n-1}{n}(1-r)\,\sigma^2$$

From this calculation the amount of correlation of the beans within a pod (r) has been determined to be $+ 0.29$.

It appears from this that the pods exhibit individuality just as the plants do. The individuality of the pods is of almost the same order as that of the plants, the average standard deviation for the beans within a pod being ± 4.3 and for the individual plants ± 3.4.

These studies do not show what the individuality of the pods is due to, whether to purely chance physiological differences as differences in nutrition or to definite morphological differentiation according to position of the pod on the plant. As has been mentioned before, there are many instances in which differences between homologous organs have been correlated with morphological position or time of development. I believe that the morphological position of the pod bears some relation to its individuality. I cannot now present quantitative results, but the material studied so far shows that there are slight differences in the form of the beans of the lowest and uppermost branches.

A further question to be investigated is whether such morphological differences as discussed in this paper may be inherited. As far as I know, there has been no work that would either prove or disprove the inheritance of such differences. Correns made some attempt to grow offspring from ray- and disk-flowers of *Dimorphotheca pluvialis*, but his material was meager and the results inconclusive. In pure-line breeding small individual differences between plants have been selected out and have maintained themselves for successive generations, and it is at least to be tested whether similar pure lines may not be obtained from a single individual.

I have material at hand, and I hope at some later time to be able to report on these questions.

THE EVOLUTION OF CELL TYPES AND CONTACT AND PRESSURE RESPONSES IN PEDIASTRUM

BY R. A. HARPER

Columbia University

I desire to present at this time an outline of the evolutionary development in the genus *Pediastrum*, noting especially also the relation of the forms of the various cell types which characterize the species to the intercellular biogenetic reactions through which the colonies get their characteristic configurations. We shall find in the subgenera a series of well-marked groups, in each of which the particular initial primitive cell form foreshadows all the types which have appeared in the evolution of this particular series. The differences which characterize the species in many cases pass over into each other by very finely graded variations, so that there has been the greatest possible confusion and uncertainty among systematists as to whether certain types should be considered species, varieties, or mere form races. An orthogenetic trend of development can be recognized in the Diactinia and Tetractinia especially and the forms illustrate such series of continuous variants as Jennings ('16) has produced by selection in *Difflugia corona*.

The genus, as a whole, on the other hand, presents a series of groups, the subgenera, which just as plainly differ by discontinuous characters. In most cases it is necessary to assume a return to the primitive undifferentiated cell type of the simplest species in order to conceive the method of origin of the subgenera.

An orthogenetic trend for the whole genus can perhaps be recognized in the simple tendency to develop spinous projections on the body of the cell, but we need to know more of the relation of such changes of form to the ultimate constitution of the cell before we can be sure that there is any common background for the tendency which has led to the formation of the one-spined, two-spined and more or less deeply lobed, three-spined, and four-spined forms which are recognized as Monactinia, Diactinia, Triactinia, and Tetractinia respectively. It is not obvious on the basis of our present knowledge why an ancestral type which had developed a unispinous form is more likely to have descendants with two- or three- and four-spined cells than with long cylindrical cells like *Hydrodictyon* or spindle-shaped cells like *Scenedesmus.*

In most cases again in the subgenera we are confronted with a series of continuous variations in the configuration of the colonies, which, however, is broken at what appear to be critical points at which a further modification of the form of the cell leads to a quite characteristic change in the symmetry of the whole colony. In some cases, cell forms which have apparently tended to a large degree of asymmetry in the colony, when modified to a certain degree, make the achievement of equal contact and pressure relations and a higher degree of symmetry possible, as in the transition from *Pediastrum simplex* to *P. triangulum* and from *P. Ehrenbergii* to *P. Rotula.* In other cases a more extreme development of a particular cell form may make a new configuration of the colony necessary with a symmetry much more difficult to achieve, as in the transition from *P. asperum* to *P. clathratum.* Throughout, as I have already pointed out ('15), we have the conflict of these orthogenetic tendencies in the evolution of the cell form and the law of cell reproduction by bipartition, giving the geometrically progressing series of cell numbers, 2, 4, 8, 16, 32, etc., with the principle of least surfaces requiring an entirely different series of numbers, 1, 7, 19, 37, 61, etc., for its full expression.

I am presenting elsewhere ('18) the results of a study of the organization, reproduction, and heredity of *Pediastrum asperum,* together with further observations on the variations in a series of seven colonies of *P. Boryanum.* The results there described are assumed in this paper. These two species represent respectively the forms with spines well developed on both peripheral and interior cells of the colony and rather large intercellular spaces, and those with small or no intercellular spaces and the spines little developed on the interior cells. In both species, I have pointed out, the cells seem in some degree directly adapted to the formation of bilaterally symmetrical plate-shaped colonies of sixteen cells. There is a considerable number of species of *Pediastrum* in which the cell form is by no means so obviously adapted to a symmetrical configuration of the colony as a whole, species in which in some cases the lobing of the cells, as noted, is carried to extremes or is of a kind calculated to result in more unstable conditions of equilibrium and a greater tendency to asymmetry in the colonies. This increase in the length of the spines and the correlated large size of the intercellular spaces by favoring floating may be adaptive for species tending to assume the plankton habit of life. These species in their relations to *P. asperum* may be considered as extreme or aberrant, though representing natural and easily conceived modifications of the cell form shown in it and in *P. Boryanum.* Such types illustrate the operation of orthogenetic tendencies in the production of results which are non-adaptive from the standpoint of the organism as it was situated when the tendency first appeared, but may become adaptive under new environmental conditions.

P. asperum apparently represents a climax type viewed from the standpoint of the possibilities of developing a least surface configuration with unit cells derived by bipartition. The deeply four-lobed form of the cells permits the best possible approximation to conformity with the circular outline and the intersection of all boundaries at 120° as found in the corresponding nineteen-unit least surface configuration.

The two-spined series has by far the largest number of species and is unquestionably the most common type, though the single-spined species, *P. simplex*, is at times found in great abundance and in almost pure growths. In general, and in all its variations, the two-spined form of cell seems to be better adapted to the formation of the anomogenous cell group with the bipartition series of cell numbers as contrasted with normal least surface groups. There is general agreement that the delimitation of species must be based on cell form and we have quite a series of types differing primarily in the degree of development and the form of the two spines.

We shall get a clearer understanding of the significance of cell form in such groups if we compare the conditions found in other species of the Diactinia with those in *P. Boryanum* and *P.*

asperum and further with those in representatives of the Anomopedium group, *P. integrum*, the Monactinia, the Triactinia, the Tetractinia, etc. I have not been able to study the reproduction and colony formation in these species and can only compare their adult forms with those I have more fully studied.

A. **Anomopedium.**—*Pediastrum integrum* Näg.

I have seen only a few specimens of *P. integrum*. The individual shown in FIGURE 1 ('18) has but seven cells, the missing cell perhaps lies at some point above or below the other cells of the colony though it can not be made out in the photograph nor was it discovered in the specimen before photographing. The species is figured by Nägeli ('49) as occurring in 4-, 8-, 16-, 32-, etc., celled colonies, all of whose marginal cells have two very rudimentary spines. All the colonies figured by Nägeli, except three of those with four or eight cells, are very irregular and he states that the regularly concentric arrangement of the cells which is common in other species of *Pediastrum* is exceptional in *P. integrum*. He also states that it is common to find the cells in two layers. Braun ('55) does not figure the species.

Nägeli gives the habitat of the species as wet cliffs. Nitardy ('14) reports that he has seen but one specimen. His figure shows that it was quite irregular and he notes that it was plainly two-layered. He explains his failure to find more specimens as due to his having been concerned especially with material from lakes, pools, etc., and notes the agreement of most authors that *P. integrum* is found on rocks over which water trickles rather than in the deeper waters of pools, etc. The question at once arises whether the irregular form of the colonies in two layers is not due to environmen-

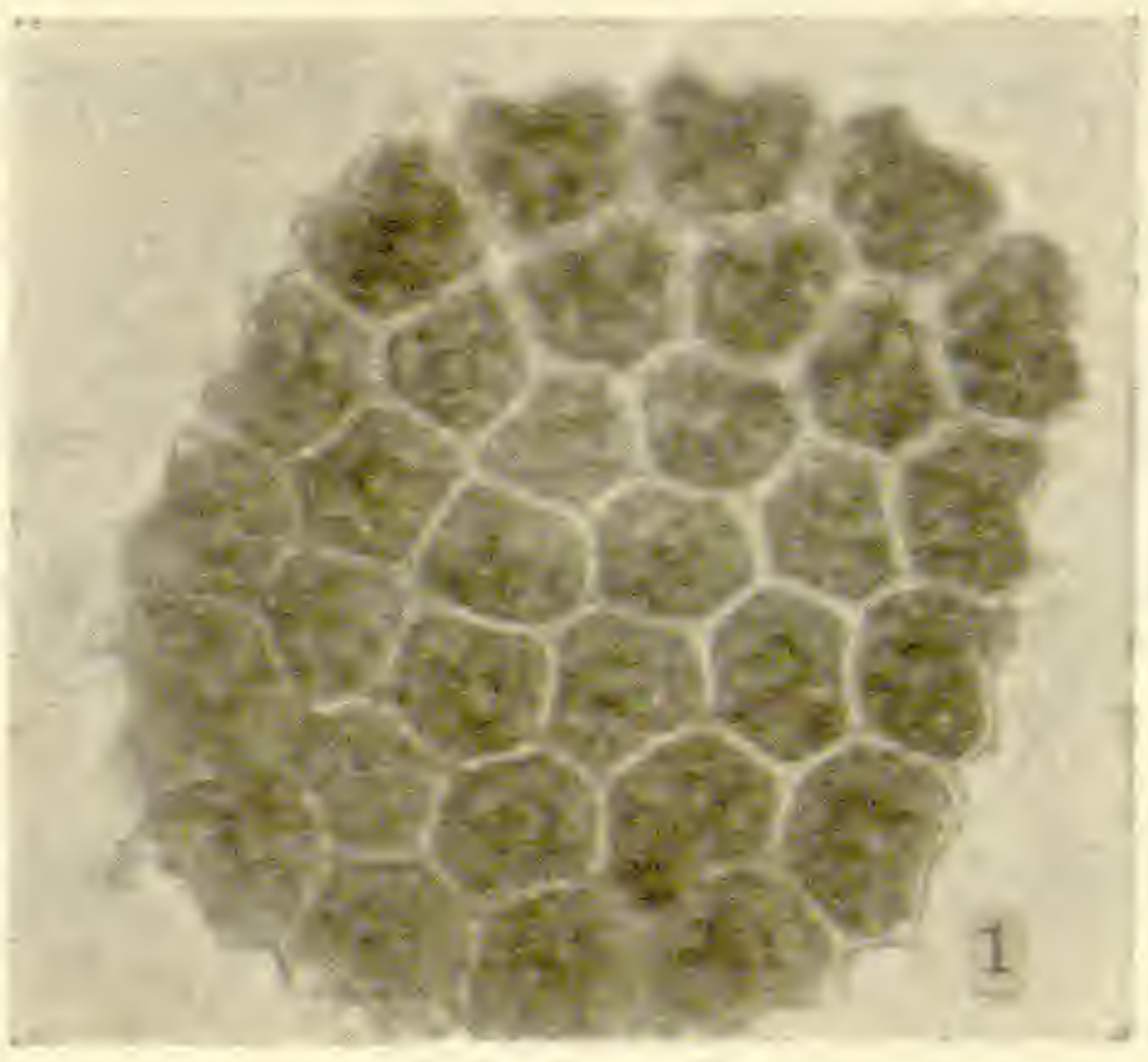


FIG. 1. *Pediastrum integrum* Näg. Perhaps the same as *P. muticum* Borge. Spines more prominent than in the eight-celled colony figured in '18, fig. 1. × about 300.

tal conditions which check the vigor of the swarm-spores just as it is checked in agar cultures of *P. Boryanum* with resulting irregularity of the colonies and reduction of the spinous projections. It seems hardly possible that *P. integrum* is only a habitat form of *P. Boryanum* but it would be interesting to grow it in water cultures along with *P. Boryanum* and observe its behavior as to cell shape and the symmetry of the colonies. I have not had the species in numbers sufficient for such experiments. The specimen shown in FIGURE I shows the thirty-two cells in one plane but the arrangement is quite irregular and asymmetrical, though there is a fair approach to the concentric circles. The short papillae seem to be quite reularly directed radially outward in the colonies so far figured, but the tendency to have certain cells out of the plane of the colony is marked and either indicates that the poles of the transverse axes of the cells and the affinities which they represent are relatively less strongly developed or that the cells are unable for environmental reasons to achieve their normal orientation and interrelations in the colony. *P. integrum* may be a species whose colonies regularly fail to achieve their typical development and yet are able to maintain themselves. I am more inclined to believe, however, that it is a primitive type in which the polarities and cell differentiations characteristic of the Monactinia and Diactinia are not fully achieved. Whether or not *P. integrum* is a good species, it may certainly be regarded as representing in the form of its cells a primitive type out of which the better adapted cell forms of the Diactinia have been developed.

B. **Monactinium.**—*Pediastrum simplex* Meyen.

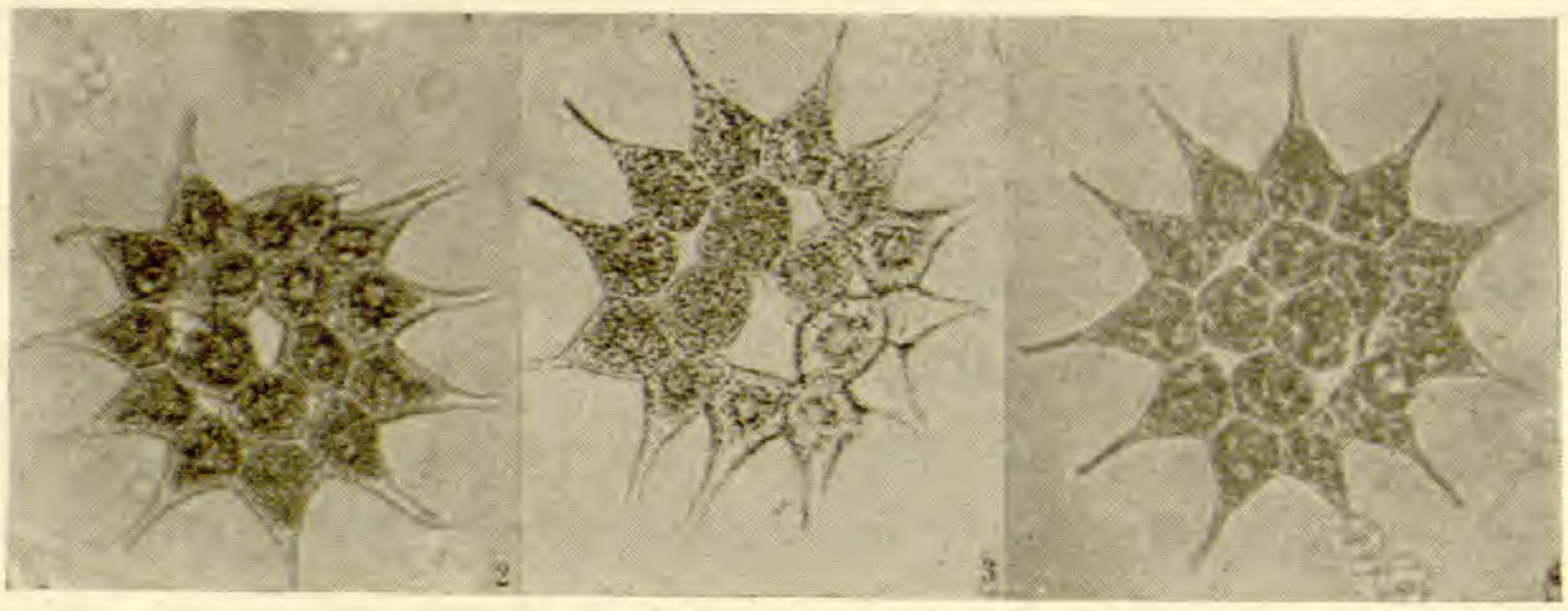
The species of *Pediastrum* whose cells show a single spine are common and widely distributed. The evidence of their variability is well shown in the fact that De-Toni ('89) believes they can all be included in one polymorphic species, *P. simplex*, while various other authors have recognized *P. duodenarium* (Bailey) Rabenh., *P. clathratum* Lemm., *P. triangulum* (Ehrenb.) A. Br., *P. Sturmii* Reinsch, etc. *P. simplex* has been described as including forms both with and without intercellular spaces.

It is impossible to determine from the evidence in the literature as to the independence of these various forms and yet there can be no doubt that in different localities and in different seasons one or another of them may be found in almost pure growths and to the exclusion of the others. It seems clear that a particular type of cell form tends to perpetuate itself, but with much fluctuation. Nitardy ('14) includes all the forms under the name *P. triangulum* (Ehrenb.) A. Br., dropping the name *P. simplex* because it has been used so variously by different authors.

I have photographs of both eight- and sixteen-celled colonies. A comparison of the sixteen-celled colonies of *P. simplex*, as I find it, with those of any species with well-developed two-spined cells suggests at once the greater capacity of the latter to form symmetrical colonies with the bipartition series of cells 4, 8, 16, 32, 64, etc. The two common arrangements in my observation seem to be, first, an irregular group of five in the center and eleven around them (FIG. 2), and, second, an irregular group of four in the center with twelve around them (FIG. 3).

The peripheral cells show their polarity by the regularity with which the spine is turned outward. Whether they are flattened enough to indicate the existence of a second differentiation in a transverse axis, I have not been able to determine. The arrangement of the inner group of cells is, as noted, quite irregular in all the colonies I have seen. Several intercellular spaces are commonly present, but show no constancy as to size, shape, or position. They may be from three- to six-sided. It is generally quite impossible to determine which side of any one of these interior cells tends to be produced into the spine. In two cases, however, I have observed an interior cell with a well-developed spine projecting into an intercellular space. One of these is shown in FIGURE 4. Whether the tendency to form the one-spined form is as fully fixed in *P. simplex* as is the corresponding tendency to form two spines in the Diactinia is not clear. It is possible that the lack of adaptation in the one-spined cell form to the production of symmetrical colonies is correlated with a failure to fix this cell form so firmly in heredity and that with an increased fixity of cell type such symmetrical forms as Nitardy's *P. triangulum* (Ehrenb.) A. Br. become possible. De Wildeman ('93), however, has observed both irregular and symmetrical colonies and includes them all in *P. simplex*. De Wildeman figures likewise only one symmetrical sixteen-celled colony ('93, *pl. 19. f. 9*) against five which are irregular, but the form of the cells in all of them is essentially the same.

Nitardy ('14) has had an abundance of the more symmetrical forms and their variants which have been variously named *simplex*, *duodenarium*, etc., and, as noted, puts them under the name *P. triangulum* (Ehrenb.) A. Br. with two varieties, *angustum* and *latum*. The latter in its cell form (Nitardy, *pl. 8. f. 5*) agrees with the forms I have found and the two varieties seem fairly well marked in the case of his figures 3 and 5, plate 8. In some of his other figures the distinction is not so clear, but the drawing is rather crude and it is hard to judge. In his variety *angustum* the lobes of the cell are more slender and form large intercellular spaces. The sixteen-celled colonies may have a very definite bilaterally and radially symmetrical arrangement of their cells with four in the center in a square, surrounded by four groups of three (Nitardy, '14, *pl. 7. f. 5*), or two groups of four and two groups of two (Nitardy, '14, *pl. 9. f. 20*), or five in the center, a pentagon surrounded by eleven—four pairs and three (Nitardy, '14. *pl. 5. f. 1*). These symmetrical figures are from his own observations on material from Grünewaldsee near Berlin and are very fine illustrations of the capacity of the swarm-spores of this species to achieve delicately balanced equilibrium relations such as are necessitated by the one-spined cell form. I have not seen these symmetrical forms and have taken from Nitardy ('14) FIGURES 27, *a*, *b*, etc., to illustrate the very interesting bilateral and radial symmetry which these sixteen-celled colonies may show.



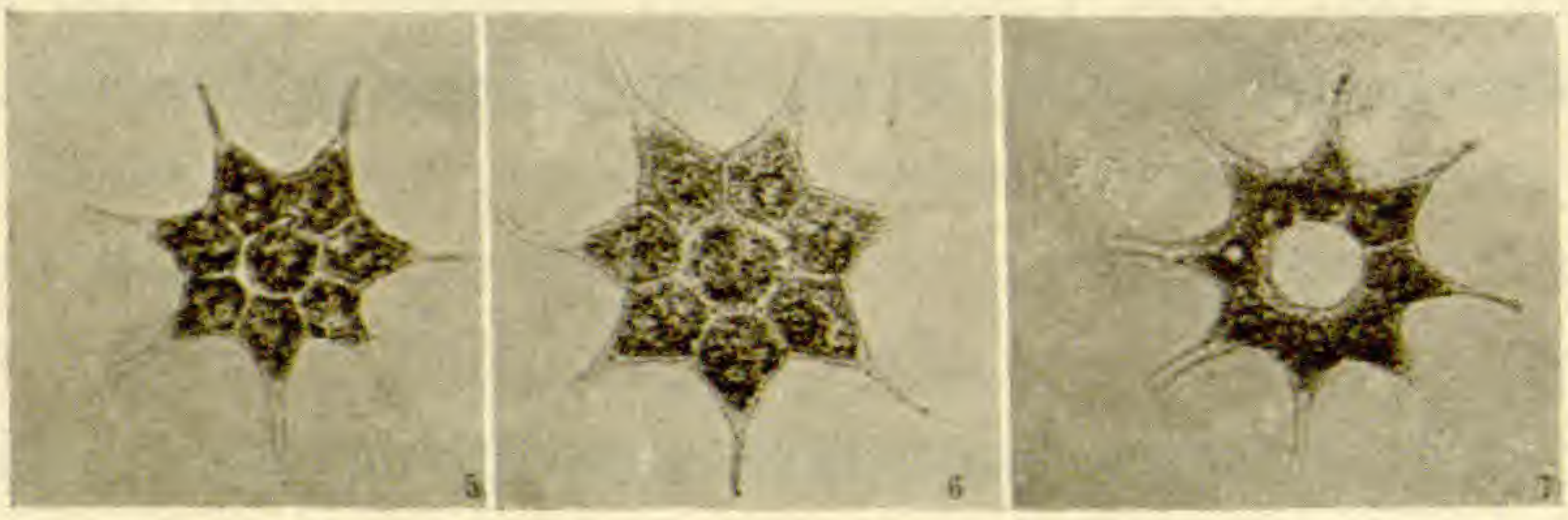
FIGS. 2, 3, and 4. *Pediastrum simplex* Meyen, sixteen-celled colonies showing the cell arrangement 5 + 11 and 4 + 12, × about 175. Figure 4 shows one of the central cells with a well-developed spine, pointing downward, but not very clearly down in the reproduction.

My material corresponds more nearly with Nitardy's var. *latum* and Nitardy gives no evidence that his var. *angustum* ever produces dense colonies with small irregular intercellular spaces like the forms of *P. simplex* I have figured. I shall refer to these bilaterally symmetrical colonies and their variants as *P. triangulum* (Ehrenb.) A. Br. (Nitardy, '14, *pl. 4. f. 4, 7, 8; pl. 5. f. 1, 2*; *pl. 6,* etc.) and to the irregular forms I have figured as *P. simplex* (De Wildeman, '93, *pl. 19. f. 14,* and perhaps Nitardy, '14, *pl. 6. f. 3*), leaving unsettled the question whether the one type can arise from the other directly as De Wildeman and others have supposed. Nitardy says he has not seen the forms without intercellular spaces such as De Wildeman has figured and evidently about Berlin the symmetrical form and its variants occur predominantly. It is not impossible, of course, that the irregular forms are merely the expression of a lack of vigor at the swarming period.

The regularity of the peripheral series in *P. simplex* even when the central cells are asymmetrically placed is doubtless due to the fact that the outer series of cells seems to come to rest sooner than those in the interior of the swarming group, as I have noted elsewhere ('18). The colonies of *P. simplex* with the irregular central groups (FIGS. 2, 3, 4) are particularly interesting as illustrating a case in which while symmetrical relations of contact and pressure are apparently impossible for all the members of the cell colony they are none the less quite perfectly achieved for a portion of the colony—the peripheral series—so far as their interrelations are concerned.

The eight-celled colonies of *P. simplex* offer fewer possibilities in the complexity of their intercellular relations and there is also much greater uniformity of type. By far the commonest arrangement is one cell in the center surrounded by seven cells (FIGS. 5 and 6). It is evident here that the single cell can hardly fill a circle made of seven instead of six cells (see FIGS. 5 and 9) and intercellular spaces tend to appear and may sometimes be quite large. In FIGURE 6, however, the central cell seems quite to fill the center of the group of eight. I have never seen a colony of this species with two cells symmetrically placed in the center and surrounded by six cells, as is so commonly the case in the eight-celled colonies of *P. Boryanum.* The markedly oblong form of the body of the central cells in *P. Boryanum* is plainly quite impossible for *P. simplex.*

I have seen a number of colonies in which (FIG. 7) all eight cells were arranged in a very perfect circle about a central rounded space. Meyen ('29) and other authors since have figured such forms. Nitardy has found it in his *P. triangulum* (FIG. 27*c*). There evidently is the tendency here to achieve a symmetrical arrangement of one sort or another—a tendency which is quite independent of the presence or absence of any adaptation in the form of the cells to the production of such symmetrical interrelations. We may assume, as in the other species, that this tendency is based on the effort of the cells in the swarming period to achieve a position in which their contact and pressure relations will be equal and balanced in as many directions as possible or that at least such pressure relations as are achieved shall be as nearly as possible mutually compensatory, as in the ring-shaped colony. The significance of occasionally achieved chance configurations is well illustrated in these cases. The symmetry of the circle is here very perfectly illustrated in FIGURE 7, but the chance that out of a swarm of eight free-swimming cells attempting to achieve interrelations of equal or balanced contact and pressure such a circle will be achieved would seem very remote. The chance for seven about one in a free-swimming group is much greater and affords a sufficiently close approximation to symmetry to make unlikely any very radically different configuration when once it is achieved. A statistical study of the relative abundance of such colonies as are shown in FIGURES 5, 6, and 7 might throw



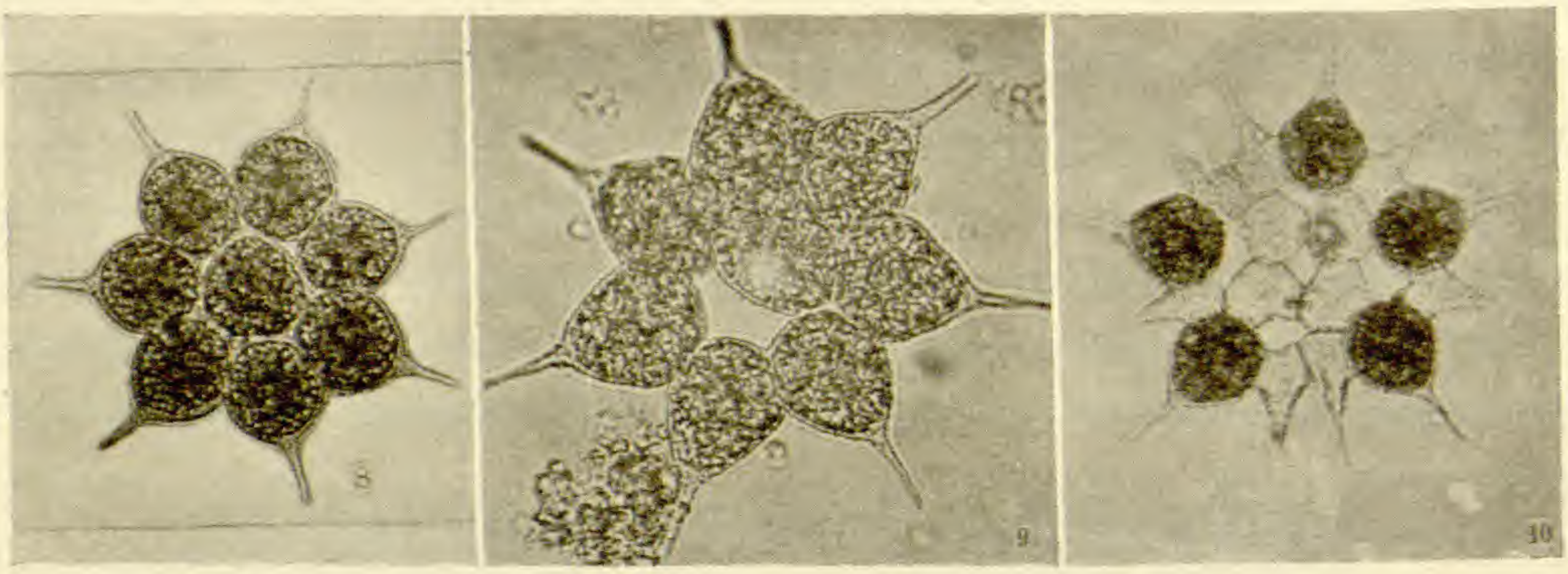
FIGS. 5, 6, and 7. Eight-celled colonies of *Pediastrum simplex* Meyen. 5, central cell does not fill space enclosed by peripheral cells. 6, no intercellular space. 7, ring-shaped colony. × about 150.

light on the question as to the relative abundance of individuals of the highest vigor as compared with those of high vigor but not the maximum.

It is evident that when in swarming the ring form is by accident once achieved it tends to persist, since it gives, as shown by its contours, the most perfectly symmetrical interrelations possible for the eight *simplex* cells. Just why the cells should tend to find their final resting position in a situation of equal or balanced pressures and contacts instead of unequal or unbalanced pressures and contacts is the same question here as in the case of other coenobes. There are obviously two factors or sets of factors involved in all these adjustments. First, it is plain that during the slow and protracted writhings of the swarm-spores of vigorous colonies the direct physical tendency of such viscid, semi-fluid droplets to adhere and yet as far as possible round up and assume a least surface configuration will have the fullest possible opportunity to come to expression. In the random movements of the swarm-spores these constantly acting physical relations will tend to maintain any accidentally achieved position which is comformable with them and to act as a check on any movement unconformable with them. Results of this sort, however, will be chiefly in evidence in the later stages of colony formation. The general arrangement of the swarm-spores in a plate or ring must be regarded as the result of the interrelations of the cells as free motile organisms involving polarities, tropisms, etc., such as are observed in other morphogenetic processes.

The grouping of eight cells in a ring rather than in a plate of seven about one in the case of *P. simplex*, which we are considering, brings out most clearly the relations of two divergent types of activity. The unconformability of a group of seven units about one—instead of six about one—with the principle of least surfaces as applied to the whole group is what prevents any swarm-spore that accidentally comes into the center of such a group (FIG. 6) from achieving equal contact and pressure relations with all the cells about it and thus leads to its changing its position until in the present case it makes one of a ring of eight (FIG. 7). This is a matter of intercellular reactions involving contact and pressure, polarities, tropisms, etc., the physical unconformability providing for the stimuli. It is obvious that the mere molecular pulls involved in least surface phenomena could never lead directly to such violent changes of group relations, though they may be of final importance in determining the exact contours of the ring when once it is blocked out, as it were, as a result of the intercellular reactions which control the earlier swarming movements.

It is then by no means enough, even when, as here, the inherited cell form is not especially involved, to identify offhand the results of these complex physiological reactions as simply the expression of the physical principle of least surfaces which, at least as at present stated, is based on intermolecular relations. If the facts are as indicated we perhaps have here in the relations of the complex reactions of these simple organisms to the widespread symmetries of form, rounded contour, etc., which are based on the physical principle of least surfaces, a suggestion at least as to the origin of the so-called aesthetic satisfaction of higher organisms in physical symmetry and balance of configuration or artistic composition. This capacity to react to inequalities in contacts and pressures or unbalanced pressures from the environment might be ascribed to a sense of symmetry and classed as one of the fundamental properties of living cells. These ring-shaped colonies of *P. simplex* certainly suggest a notable delicacy of response to pressure and contact stimuli.



FIGS. 8, 9, and 10. *Pediastrum simplex* Meyen, of the form known as *P. Sturmii* Reinsch. 8, with small intercellular spaces, × about 200. 9, with a large intercellular space, × about 250. 10, sixteen-celled colony, eleven cells empty, *simplex* type, and five cells about ready to form swarmspores, *Sturmii* type, × about 200.

Pediastrum Sturmii Reinsch, characterized by plumper, more rounded cells with spines supposed to be solid instead of hollow, may be represented by the form I have shown in FIGURES 8, 9, and 10. In my opinion, these are merely colonies of *P. simplex* approaching the reproductive stage, but I have not so far observed swarm-spore formation in the species. Nitardy ('14, p. 178) regards a warty surface, pentagonal peripheral cells, and the non-tapering form of the spine as important characters of *P. Sturmii.*

FIGURE 10 gives quite convincing evidence on this point. In this colony five of the cells are well advanced toward reproduction while the remaining eleven have remained immature. The mature cells have the form characteristic of *P. Sturmii;* the immature cells are like those of the ordinary colonies of *P. simplex* which have not yet reached the reproductive stage, but it is to be noted that the cells in this colony are much smaller than in the other two. The change in form of the cells as they approach the period of reproduction is very marked. Their rounding up leads to the at least partial withdrawal of material from the lobes and a narrowing of their bases. Failure to recognize these changes may be responsible for confusion as to the real character of *P. Sturmii.* Professor B. M. Davis has kindly shown me, and permits me to refer to, as yet unpublished figures showing the reproduction of *P. simplex* which seem to me not inconsistent with this view.

In FIGURE 11 I have been able to bring out faintly, in my original prints, the curious bristle-like appendages at the ends of the spines, which like the similar structures in plankton diatoms tend to keep the organism afloat (see Petersen, '11, and Zacharias, '03). As shown here, it is clear that the individual setae may be widely divergent or almost parallel. The suggestion that they are movable on their bases or points of insertion in the spines is very obvious. The nodular or pear-shaped swellings at their bases are also very conspicuous in the case of the widely spread group from the spine of cell *a* and may very well be contractile droplets of cytoplasm functioning as motile organs.

This colony is further interesting from the fact that the cell *a* seems relatively large as compared with the cells next to it. The whole colony also shows only fifteen instead of sixteen cells. As Nitardy and others have emphasized, the law of bipartition and the resultant 4-, 8-, 16-, 32-, etc., cell numbers are very firmly fixed in the colonies of *Pediastrum.* It is possible that the sixteenth cell lies above or below the plane of the colony in this case and hence does not appear in the photograph. On the other hand, it may be that cell *a* did not undergo the third division and has remained larger than its fellows.

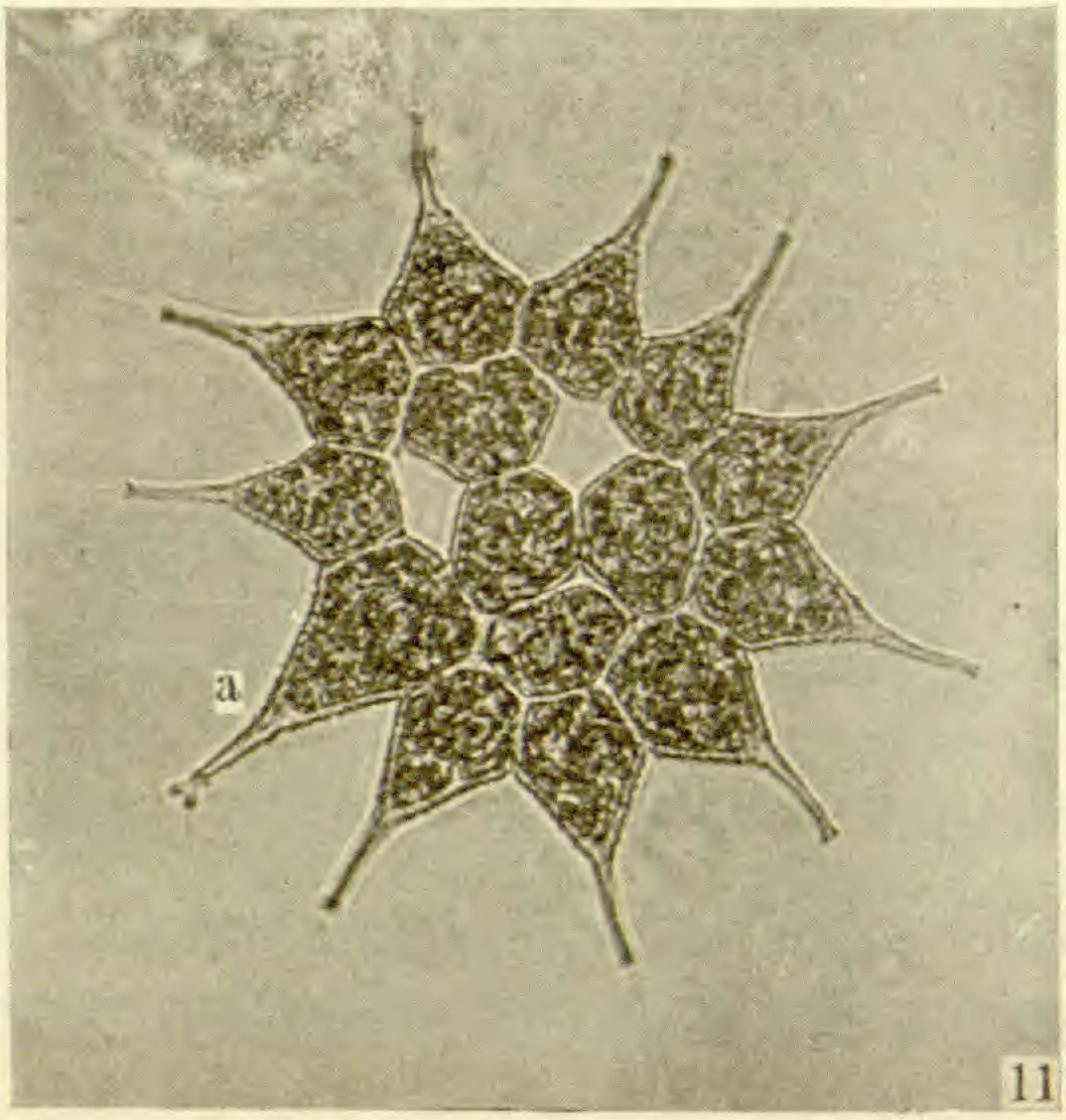


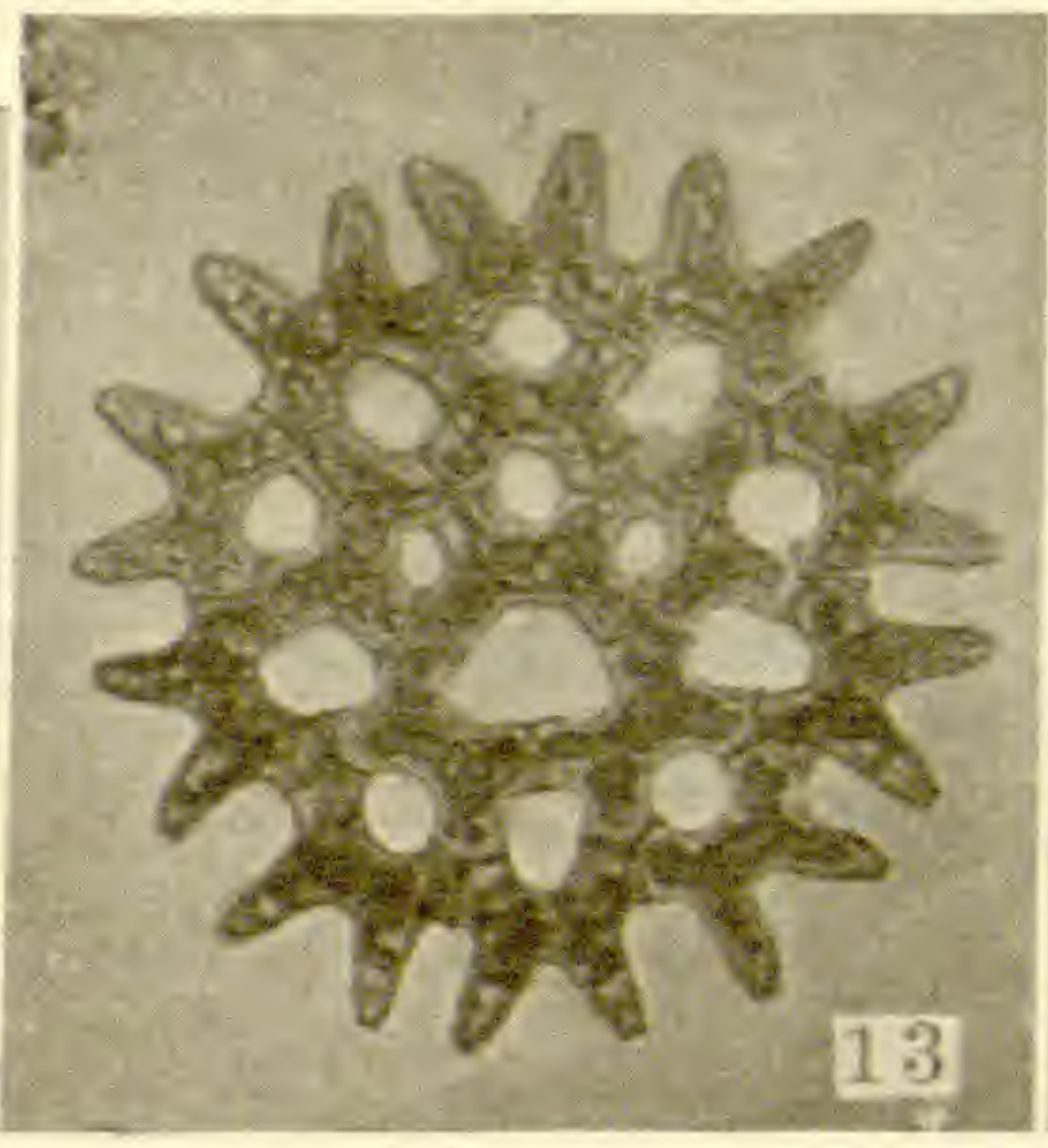
FIG. 11. *Pediastrum simplex* Meyen. Fifteen-celled colony, one cell, *a*, larger than the others; bristles and pear-shaped basal bodies show on some of the spines in the original, but are practically lost in reproduction. × about 400.

Nitardy ('14, p. 183) figures a specimen of *P. Boryanum* with fifteen cells, one of which is much larger than the others and contains a double pyrenoid. There is also a faint line running across the middle of the cell and Nitardy is convinced that the large cell has arisen by fusion of two swarm-spores. He notes that this is the only case of anomaly in cell number which he has observed in twenty years of study of the group. It would seem that the large cell might equally well be due to a failure of one of the cells to complete the third division. The larger size of the cells in the sixteen-celled daughter of a thirty-two-celled colony ('18, FIG. 21) as compared with the thirty-two-celled daughter of the same mother is conspicuous.

C. Diactinium.

In the Diactinia we have the largest and most common of the subgenera of *Pediastrum*. The delimitation of species, however, seems in high degree difficult and uncertain. De-Toni ('89) recognizes eight species in the group with eight varieties under *P. Boryanum* (Turp.) Menegh. and seven varieties under *P. duplex* Meyen, many of which are regarded by other authors as good species. Nitardy ('14) believes the whole series can be best regarded as three species with three varieties under *P. Boryanum* (Turp.) Menegh. and three varieties under *P. pertusum* Kütz.

Braun ('55) gives no figure of his *P. pertusum* Kütz. var. *clathratum*, but refers to figures of Meyen ('29), Hassall ('45) and Corda ('39, *pl. 3. f. 18*). Corda's figure of *P. diodon* is certainly unreliable. Meyen's figures, though poor, seem to agree rather better with Lagerheim's figures of his var. *reticulatum* ('82) than with those of De Wildeman ('00, p. 104, *f. 17* and *18*), which are labelled *P. duplex* var. *reticulatum* Lagerh., and those of Chodat ('01, p. 227 and 228) labelled *P. duplex* Meyen and *P. duplex* f. *genuinum* (A. Br.). Hassall's figure ('45, *pl. 92. f. 4*) is certainly widely different from those of De Wildeman and Chodat. It seems doubtful whether Nägeli ('49), Braun, or Lagerheim had these 5 + 11 forms figured by De Wildeman, Chodat, and Nitardy ('14, *pl. 8. f. 11*). Both types are found in this country



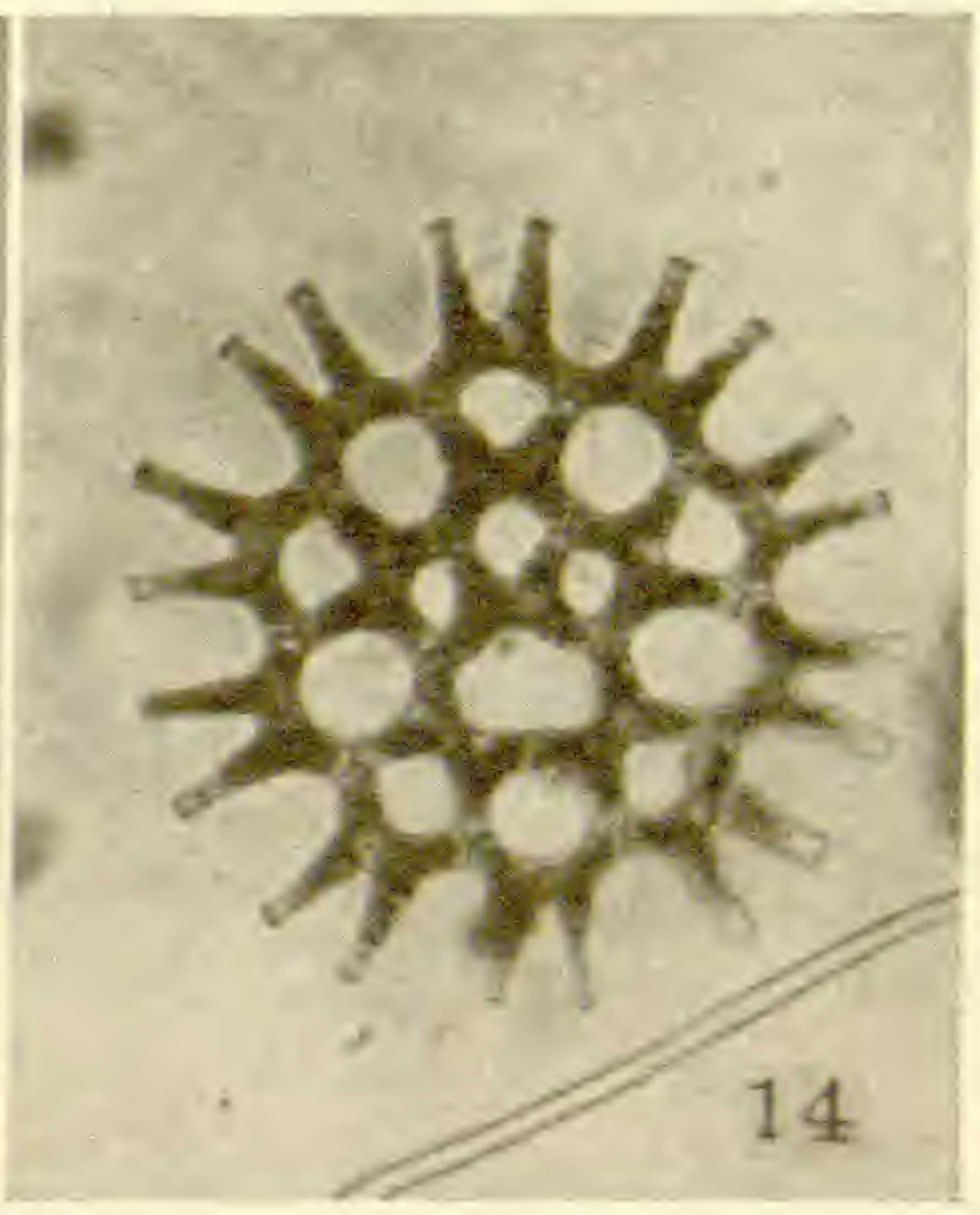


FIG. 12. *Pediastrum Boryanum* (Turp.) Menegh. Sixteen-celled colony typical arrangement, form with slender equal spines, × about 300.

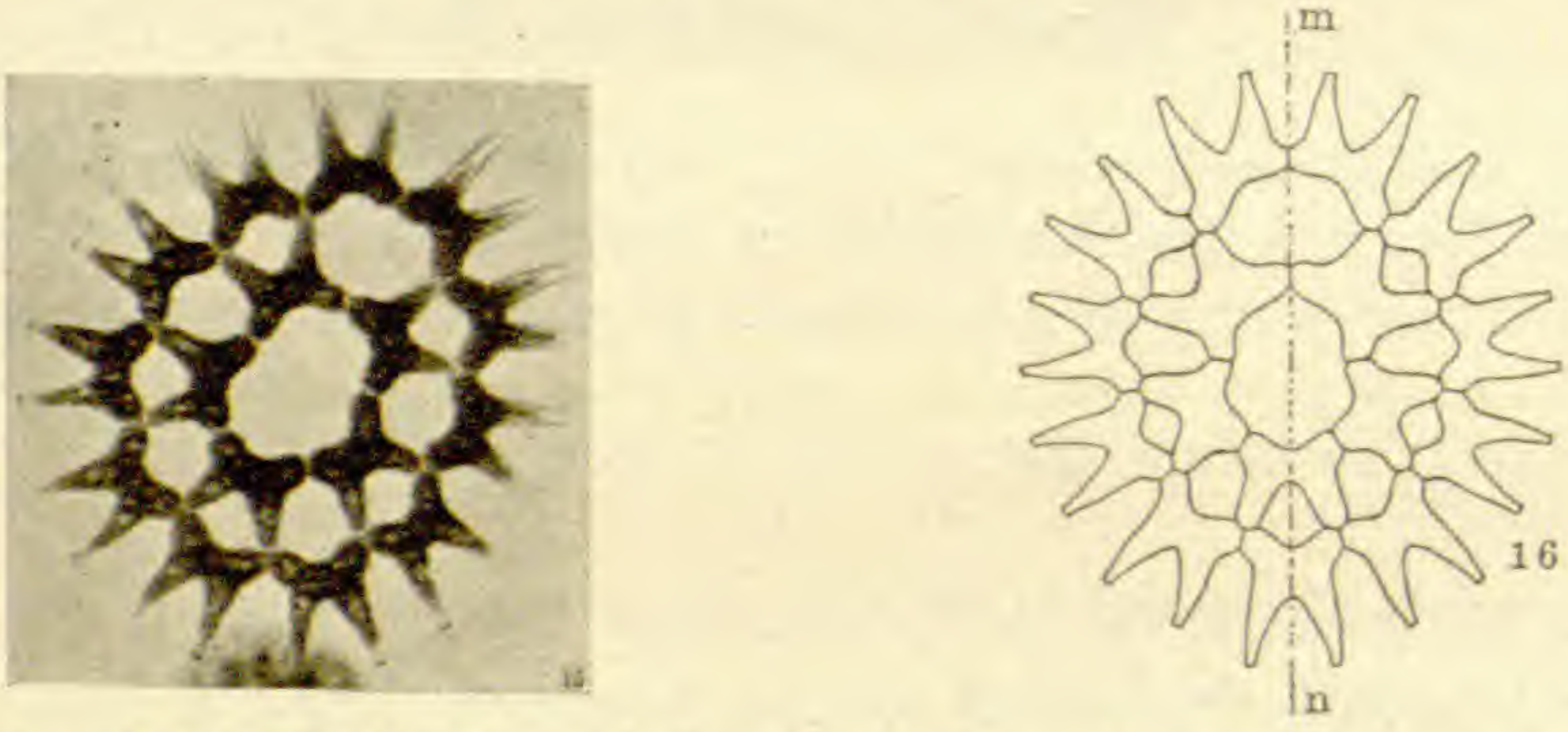
FIG. 13. *P. asperum*, sixteen-celled colony, typical form, × about 425.

FIG. 14. *P. duplex* Meyen, var. *reticulatum* Lagerh. Intermediate between *P. asperum* and *P. clathratum* (figs. 15–21), × about 300.

and cultures will have to show whether they both can be produced from the same mother colony. Until the question is settled it is certainly more convenient to keep them under the old names of Meyen, Kützing, and Braun. I shall call the type shown in FIGURE 14 *P. duplex* Meyen var. *reticulatum* Lagerh. (Meyen, '29, *pl. 43. f. 16 and 17*; Lagerheim, '82, *pl. 2. f. 1*), and the forms shown in my FIGURES 15–21, *P. clathratum* A. Br., *P. pertusum* Kützing, may very well be Braun's var. *asperum*, though there may be a form with smooth spines connecting *P. asperum* with *P. Boryanum*. This form of mine (FIG. 14) is plainly Lagerheim's *P. duplex* var. *reticulatum* ('82, *pl. 2. f. 1*).

P. clathratum A. Br.

In *Pediastrum clathratum* A. Br. we have a species of the Diactinia in which the four-lobed cell type has been carried to its extreme development. It is a fairly common and abundant species, apparently vigorous and well adapted to the conditions it finds. In the extreme length of its cell lobes as compared with other species of the Diactinia, *P. clathratum* is obviously a climax type. What we may call the body of the cell in *P. Boryanum* (FIG. 12) has gone over almost completely into the four spinous lobes. The cell is quite H-shaped, with cross-bars little or no thicker than the arms (FIGS. 15–18). As a result, the adaptation of the lobed form of the cells to the exigencies of colony formation, with cell numbers



FIGS. 15 and 16. *Pediastrum clathratum* A. Br. Sixteen-celled colony and type diagram. Fig. 15 × about 300.

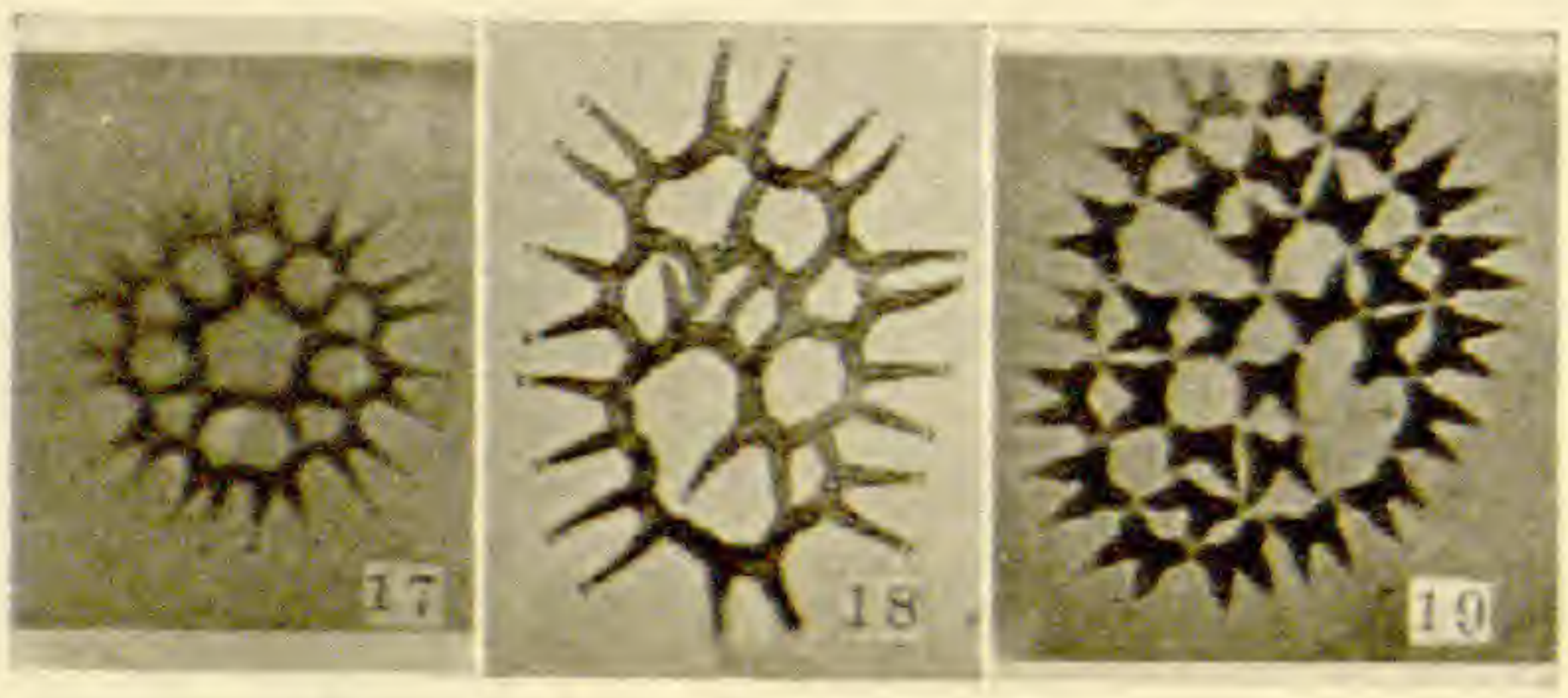
produced by bipartition, works out in quite a different way from that in *P. Boryanum* and *P. asperum* (FIG. 13). It is a type in which the four-lobed form in its extreme development has resulted in a reduction of stability and compactness in the organization of the colony as a whole. The result is a light and open structure which may be better suited to conditions of life in the plankton.

The intercellular angles are hard to measure because of the very limited areas of contact between the cells but there can be no question that the variations from 120° are so slight as not to be accurately determinable by the means I have used. The slenderness of the lobes makes possible in the highest degree compensatory curvings and bendings so as to give quite equal pressure and tension relations between the surfaces of contact of the cells. The extreme length of the lobes has brought with it a new type of cell grouping in the colony. I have had an abundance of material of this form and have not seen a single sixteen-celled individual with the common cell arrangement 1 + 5 + 10, found in *P. Boryanum* and *P. asperum*.

Nitardy (*pl. 8. f. 13*) refers to *P. clathratum*, a sixteen-celled colony with the ordinary arrangement found in *P. asperum* 1 + 5 + 10. The cell form also is plainly that of *P. asperum* rather than that of *P. clathratum*. Chodat's ('01) figures of what he identifies as *P. duplex* are both of the *clathratum* type. His figure 151 is of an irregular older colony nearer the stage of reproduction, but figure 152*b* shows the type configuration of the cells.

The type arrangement seems to be that shown in the diagram (FIG. 16), five cells surrounded by eleven cells and the center of the colony an open pentagonal or oblong area. Such a colony is bilaterally symmetrical about the axis *mn*, as shown in the diagram. The outer series of cell contacts is in threes except at the pole *m*, where there is a contact between two. The inner series of contacts is all in twos. The central intercellular space is, as noted, pentagonal and more or less elongated in the axis of the colony. With the variation in the shape of the central intercellular space the whole colony becomes either rounder or more oblong. Compare FIGURES 15 and 17. In correlation with the length and slenderness of its cell lobes *P. clathratum* is a climax form in its development of intercellular spaces. The outer series of intercellular spaces consists of five inequilateral lens-shaped and five shield-shaped openings bounded by two and three cells respectively, with the large oval and four-cornered intercellular space near the pole *m*, bounded by four cells and bisected by the axis of symmetry of the colony. No such configuration is found, so far as I have observed, in any other species of the Diactinia so far described, and yet the cell form shown in FIGURE 14 connects *P. clathratum* with *P. asperum* very closely. This figure is from material collected in Wisconsin and I have quite a series of photographs showing cells of this form in colonies with 16, 32 and 64 cells, but I have never seen one of these colonies with the 5 + 11 cell configuration of *P. clathratum*. My figures of *P. clathratum* are from material collected at Woods Hole, where the typical form is common as well as the less developed types of *P. asperum*, but I have not found with these forms colonies exactly like those from Wisconsin.

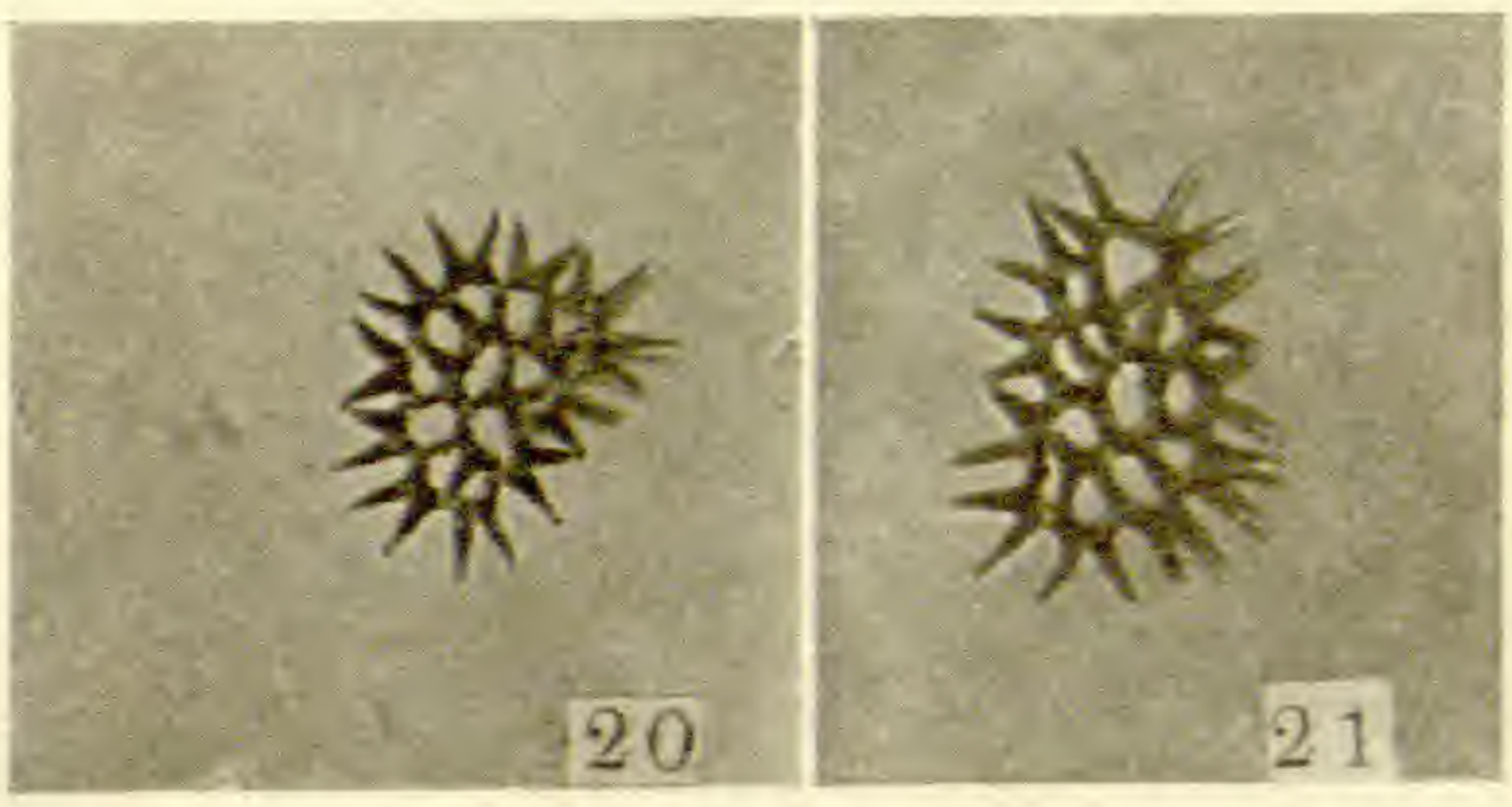
We have here two types, which, as the confusion in the literature shows, can be connected very closely by all possible intergradations in cell form and yet it seems clear that either when the modification of the cell form passes a certain point or as a result of modifications of the cell polarities a change in the type configuration of the colony results. There is no good evidence in the literature that colonies with the 5 + 11 configuration of *P. clathratum* and those with the 1 + 5 + 10 configuration of *P. asperum* can arise from the same parent colony and, as noted above, it must be left to further culture work to show whether this is possible.



FIGS. 17, 18, and 19. *Pediastrum clathratum* A. Br., irregular colonies. 17, circular colony, × about 175; figure 18 showing quite clearly the pear-shaped bodies at ends of spines, × about 200. The colony shown in figure 19 is about ready for reproduction, × 175.

The configuration of such colonies as those shown in FIGURES 15–17, involving the absence of a central cell, the increased variety of form in the intercellular spaces, and the increased number of paired cell contacts is certainly more complex and further removed from that of a simple 1 + 6 + 12 least surface group than is the type of sixteen-celled colony of *P. asperum* (FIG. 13). Greater delicacy in the contact and pressure responses of the swarming zoospores is certainly necessary to achieve it. It is the most highly specialized configuration I have yet observed in any of the species of the genus, though whether greater delicacy of response is necessary for its production than for that of the ring-shaped eight-celled colony of *P. simplex* is not easy to say.

The colonies are very commonly irregular and indicate very clearly that the normal contact relations are not necessary for the development of the typical cell form, as is illustrated by the interior cell with one free spine shown in FIGURE 18, and by De Wildeman's ('00, *f. 18*, p. 104). I have been able in several cases to observe the reproduction of the species. The cells become much swollen but still show a very deeply lobed form as compared with *P. asperum* at the corresponding stage. FIGURE 19 shows a thirty-two-celled colony which is about ready for reproduction and FIGURES 20 and 21 show two very irregular young colonies, whose birth I observed in a sealed preparation. They are only a few hours old but the cells show the contours characteristic of the species. It is of interest to compare these figures with FIGURE 14 as to the forms of the cells.



FIGS. 20 and 21. Young, irregular colonies of *Pediastrum clathratum* A. Br., × about 400.

The whole colony is relatively fragile and is ordinarily bent and curved so as to make a good photograph impossible. The bristle-like projections from the ends of its cell lobes are extremely well developed and are brought out faintly in some of my photographs. The colonies are very sensitive to currents in the water and seem almost self-motile at times. It is very difficult to find one quiet enough for photographing and the varying position of the apical bristles, now all close together in a parallel pencil and now widely diverging as shown in my figure of *P. simplex* (FIG. 11), would seem perhaps to be a factor in the wabbling, tipping, and trembling movements of the colonies. I have, however, seen no movement of the bristles. The species illustrates the possibility that an orthogenetic tendency which is adaptive in a specific particular when moderately developed may in its extreme development become adaptive in quite a different connection.

P. angulosum (Ehrenb.) Menegh.

This form (FIG. 22) represents a type of the diactinial cell which seems quite remarkable for its constancy and the name and species have been less juggled with by descriptive writers than many others. The characteristically short oblique spines with the wide sinus between them show very clearly that the morphogenetic tendency to the production of such projections involves other factors than merely those of length. It is a widely distributed and fairly common form and yet apparently has developed no such series of fluctuating variants as have *P. Boryanum* and *P. pertusum*. De-Toni ('89) recognizes no varieties of it. Nitardy ('14) has apparently never seen it and refers it without adequate evidence to *P. Boryanum*. The colonies tend to high cell numbers and in the 32- and 64-celled types have quite regularly a somewhat reniform outline which is suggested also in the sixteen-celled colony. That the cell form is in any way adapted to or determines this configuration of the colony is not obvious, and the form-determining factors are not so readily recognizable as in the other Diactinia.

FIG. 22. *Pediastrum angulosum* (Ehrenb.) Menegh. Irregular sixteen-celled colony, × about 325.

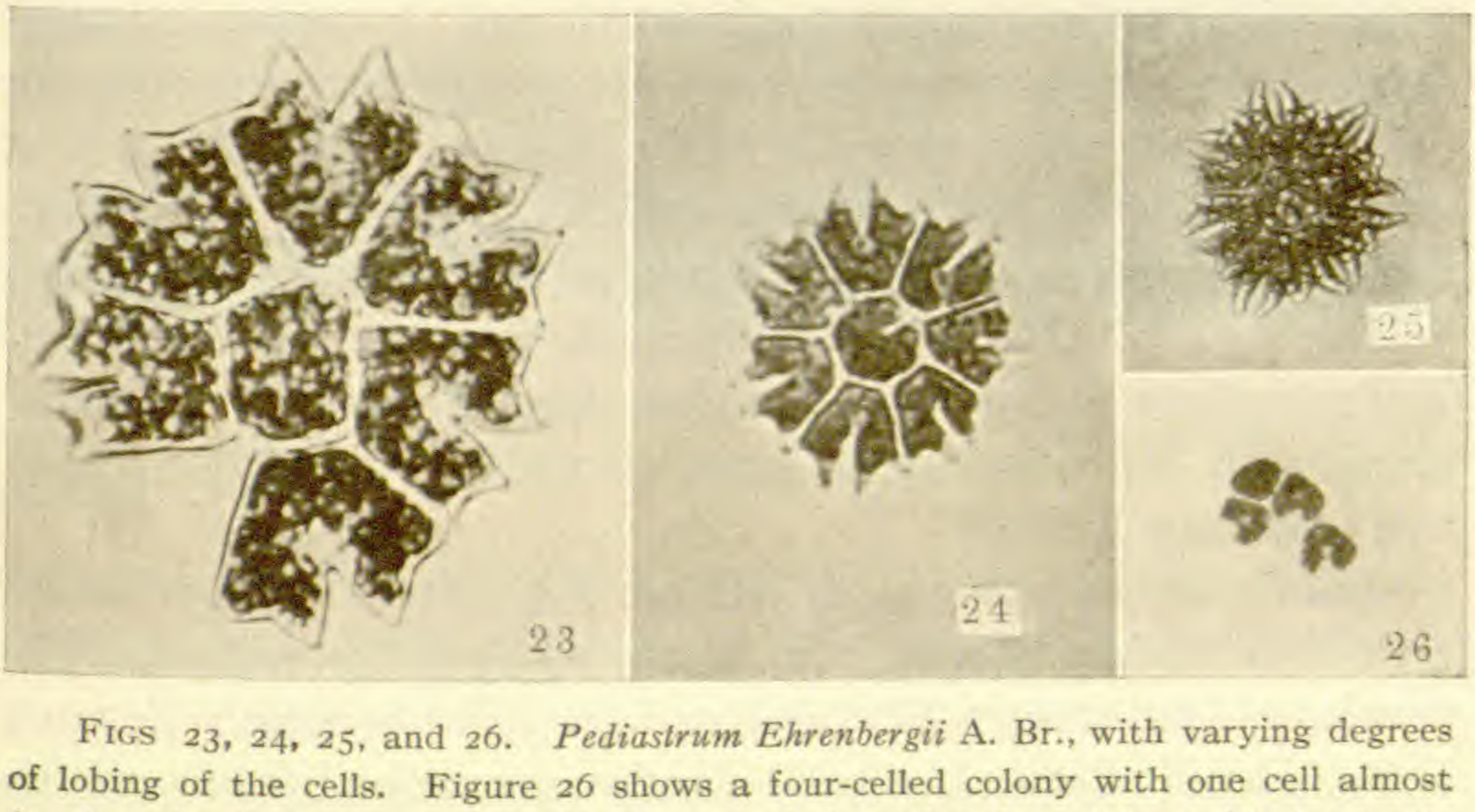
I shall discuss the species further in considering the general question of the relation of the larger cell numbers to the configuration of the colonies in another paper. The shortness and form of the spines suggest in some degree those of *P. Ehrenbergii*, but the species cannot be regarded as in any proper sense a transition form between the Diactinia and Tetractinia.

D. *Pediastrum tricornutum* Borge.

This species, representing perhaps a series of *Triactinium* (Nitardy makes it *Diactiniopsis*), I have not seen. It differs characteristically from other types in that the three spines do not lie in the same plane and hence have no part in determining the intercellular contacts in the colony. Only eight-celled colonies have been figured so far—one cell in the center surrounded by seven. Such a form could hardly be conceived as developing from the Diactinia by progressive variation. It may have originated from a form like *P. integrum* as a representative of quite a different line of development or it may have connections with *Coelastrum* in quite a different series.

E. **Tetractinium.**—*Pediastrum Ehrenbergii* A. Br.

The Tetractinia illustrated by the common *P. Ehrenbergii* (FIGS. 23, 24, 25, 26) are those types in which the two spines or lobes of the Diactinia tend to become more or less deeply bifid. The species commonly occur in four-, eight-, and sixteen-celled



FIGS 23, 24, 25, and 26. *Pediastrum Ehrenbergii* A. Br., with varying degrees of lobing of the cells. Figure 26 shows a four-celled colony with one cell almost free but showing none the less the characteristic wedge-shaped form, × about 350. Fig. 23 × about 1000, Fig. 24 × about 700, Fig. 25 × about 550.

colonies and consist in the latter of a group of four or five central cells surrounded by, respectively, twelve or eleven peripheral cells.

In this group again the splitting or doubling of the spinous projection of the cell in its incipient stages foreshadows the further development of this character through the whole series. The incised or bifid tips and the doubling of the spines appear in graded stages of development which suggest very strongly that the species have been produced as end members in series of continuous variants. Under *P. Ehrenbergii* and its synonyms we find included by most authors forms in which the degree of lobing varies widely. In some forms the cells are only bluntly bifid (FIG. 26). In others there is every degree of inequality between the two points of the bifid spine, suggesting that the forms may have arisen from the Diactinia by the budding off of an accessory tooth on the main spine, or at another point on the body of the cell rather than by splitting the tip of the spine itself (FIG. 25).

Nitardy's treatment of the group recognizes the depth of lobing and the degree of separation of the points as the principal basis for distinguishing the types and his two species, with a variety under the first, form what it seems to me is in part at least a natural series.

In his first species, *P. incisum* Hassall, however, Nitardy includes forms with the spines very unequally cleft (FIG. 24), one half frequently much more strongly developed ('14, *pl. 5. f. 7* and *pl. 7. f. 8*) along with others in which the spines are very short and even blunt ('14, *pl. 7. f. 6, 7*, and *11*). There is no adequate evidence that all these forms could come from one mother colony. In the variety *P. incisum* var. *Rota* Nit. he includes a natural group with the spines much more strongly developed and as a rule quite equally bifid.

In the second species, *P. lobatum* Nit., he includes what he regards as the handsomest forms in the whole genus, with strongly developed lobes deeply bifid (*pl. 5. f. 4*). This is plainly Braun's and Cooke's *P. Rotula* Ehrenb. The five species and four varieties recognized by De-Toni also show characteristic differences in the cell form and lobing but reliable figures are not available for grouping them in an evolutionary series.

I have never seen in *P. Ehrenbergii* the 1 + 5 + 10 configuration which is so common in the Diactinia. In the eight-celled colonies the common arrangement is 1 + 7, with the central cell having the appearance of being rather crowded and suppressed in its development though quite regularly showing the narrow notch characteristic of the cell form of the species (FIG. 24). This apparent crowding of the central cell in a group of 1 + 7 is quite contrary to what one observes in *P. simplex* and other species. It is due to the pronouncedly wedge-shaped form of the cells. That the cell form is, as in other species, hereditary and not dependent on the pressure of adjacent cells for its development is shown in FIGURE 26, which represents an irregular four-celled colony, one of whose cells is almost free and has none the less developed the wedge-shaped form.

The quadrifid cell form apparently does not lend itself to the formation of symmetrical least surface configurations with regular intercellular spaces as does the duplex form. I have seen no colonies in which there was any indication of the utilization of the quadrifid character in the interior cells of a colony in developing symmetrical intercellular relations. Braun's figures of *P. Rotula* ('55, *pl. 6. f. 5–12*) suggest that such cases may exist. Braun's figure ('55, *pl. 6. f. 5*) and Cooke's figure ('84, *pl. 18. f. 2d*) are fine examples of bilateral symmetry in eight-celled colonies of *P. Rotula* Ehrenb. In the sixteen-celled colonies the central group of four or five may make a ring with a four- or five-sided intercellular space in the center and the peripheral cells may also make a very perfect ring-formed series of eleven or twelve. There are, however, no relations of symmetry further than this general concentricity between the cells of the two series shown

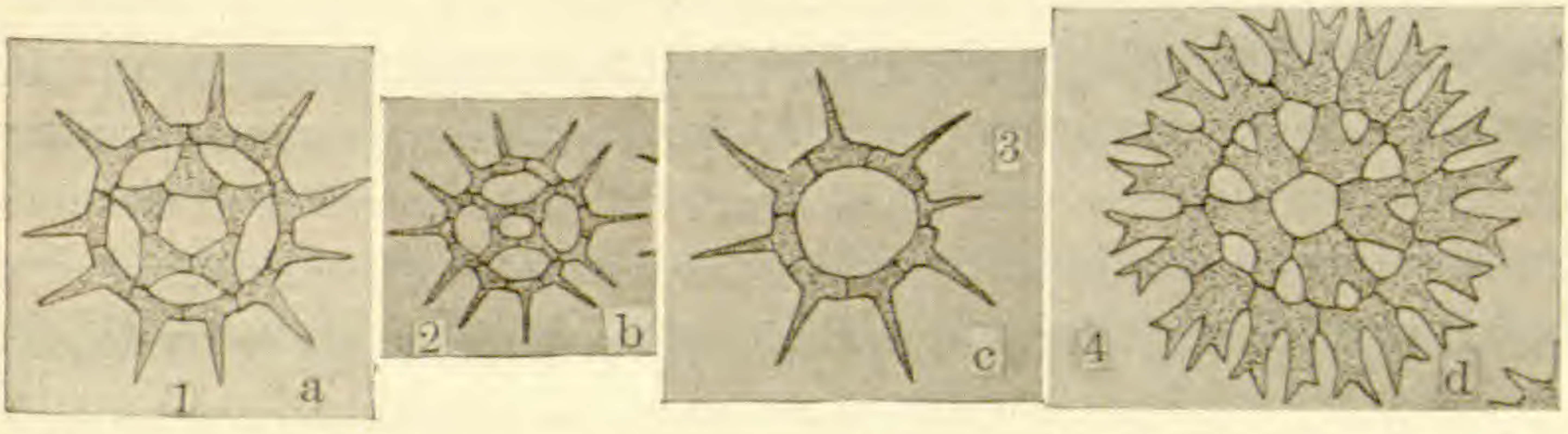


FIG. 27, *a, b, c, d.* Reproduced from Nitardy ('14). *a, b, c, P. triangulum* (Ehrenb.) A. Br.; *d, P. Rotula* Ehrenb., sixteen-celled colony showing bilateral symmetry.

in any figures except one by Nitardy ('14, *pl. 5. f. 4*), which I have reproduced (FIG. 27*d*). It would seem that the tendency to lobing which fits so perfectly with the principles of least surfaces and binary fission in the simpler forms of the diactinial type has here gone too far and become distinctly non-adaptive as far as the symmetrical grouping of the cells is concerned. The tendency to the lower numbers of cells in the colonies of these species is, if real, a curious correlation, since the quadrifid form of the cells would not in any case seem capable of limiting the number of times they should divide in reproduction.

DISCUSSION

The general relations of the *integrum*, Monactinium, Diactinium, Triactinium and Tetractinium types suggest at once certain evolutionary possibilities and limitations in very clear form owing to the extreme simplicity of the characters involved. Evolution in the whole group has proceeded by modification of the cell form. It is quite obvious, as noted, that a species with one spine could not become gradually modified into a species with two spines in any other way than by returning to the spineless type and then advancing on quite a different line of development resulting in typically different intercellular relations in the colony. We have no evidence of the possibility of transforming a *simplex* type into a two-spined type by the gradual development of a second spine in addition to the one already present or by splitting the single spine. A form with one long, well-developed spine and one short, rudimentary spine is not only unknown in nature but is quite inconsistent with the colonial organization of the cells in the plate-shaped groups which are characteristic of the whole genus. The only obvious evolutionary routes from a one-spined to a two-spined type are either as noted by a change back to the primitive *integrum* type and a new start in a characteristically different direction or by sudden mutational transformation, perhaps to be considered a reduplication, by which a form with one spine becomes at once a form with two equally well-developed spines. There is an analogy here with the reduplications in the lobing of fern fronds and pinnae by which the common sports of the Boston fern have been produced (see Benedict, '16).

That it is mere analogy is, of course, obvious from the fact that the phenomenon is intracellular in the one case while in the other it involves the morphogenetic behavior of many-celled tissues and organs. Given this change of cell form and the diactinial type of colony would result directly, the same polarity and cell interrelations being involved in both cases.

We have, further, manifestly orthogenetic groups in most of the subgenera. Given the tendency to the development of two spines and the species of the two-spined group are at once foreshadowed as are the species of the Monactinia, Triactinia, and Tetractinia by the presence of the possibility of developing one-spined, three-spined and four-spined or bifid-spined cells, respectively. Given cells which adhere in groups, at the same time having a tendency to develop thick spinous projections with catenoidal deformation of the entire cell body, and the whole genus is foreshadowed. Such series certainly illustrate one form at least of the many types of change which have been characterized as orthogenetic, though the use of such a term is not specially illuminating in the absence of evidence as to the structural features of the cells which have determined their characteristic forms. A fuller cytological study of the cells of *Pediastrum* may serve to throw light both on the nature of cell polarities and the means by which such orthogenetic transformations are brought about.

The transition from the *simplex* to the two-spined type, as noted, could only come about either by a change giving the new character in functional development at once or by a return to the primitive *integrum* type and a new start. The same is true as to the possibility of change from the two-spined to the three-spined type. On the other hand, the change from the *simplex* to the trispinous form might quite well come about by the gradual development of two additional spines with or without the degradation of the single existing spine. To be sure, the three spines do not lie in the plane of the colony as does the single spine, but the readjustments which this difference between the two types involves are by no means inconceivable.

It is notable that in *Pediastrum clathratum* the interior cells show almost as fully developed lobes as those on the periphery and in this respect again I am inclined to regard it as a more specialized type even than *P. asperum*, though it is obvious that there is less differentiation between its cells than is found in *P. Boryanum*, in which the interior and the peripheral cells differ notably in their form. In *P. clathratum* and *P. asperum*, however, the hereditary cell form has become apparently so fixed that it comes to expression even under the difficult conditions of the interior cells. If, as I have suggested ('18), the adaptive oblong four-lobed cell form originated and developed in direct response to the environmental limitations and stimuli imposed on sixteen cells adhering in a plate-formed colony and with a tendency owing to their partially fluid consistency to assume a surface tension form, *P. clathratum* certainly represents the most extreme expression of this evolutionary trend. The advance has been from such unspecialized and uniform cells as those of *P. integrum* through *P. Boryanum* with its cell differentiations to *P. asperum* and *P. clathratum* where all the cells are much alike again but vastly more specialized in form.

The relations of *P. simplex* and *P. triangulum*, as I am recognizing them, illustrate the same point. In the sixteen-celled colonies of *P. simplex* the interior cells differ regularly from the peripheral cells by the absence of the spine, though as shown in figure 4 an interior cell will develop a spine whenever it is so placed with reference to an intercellular space that this is possible. In *P. triangulum* both interior and peripheral cells develop spines and the configuration of the colony is altered accordingly by the achievement of symmetry relations which permit each cell to express much more fully its inherited form tendencies. That these form tendencies are really present equally in all the cells of *P. simplex* also is shown in the eight-celled ring-shaped colonies where every cell has an equal chance to achieve its full morphogenetic possibilities and the result is a remarkable uniformity in the size and shape of all the cells.

The development of spines and the four-lobed cell form in *P. asperum* seems to have to do with the compactness and surface tension relations of the cells in the colony as a group, while in *P. clathratum* the length of the spines results in a light, open structure of the colony perhaps adapted to life in the plankton.

Schroeter ('97) and many others have noted that various species of *Pediastrum* may be plankton organisms.

The gradual appearance of the bifid spine in the Tetractinia is certainly a further development of the tendency to lobing of the cells and the group forms an obviously orthogenetic series, but here the bifid spine is quite unadapted to the development of cell groups with the bipartition cell numbers. In cases where symmetry, either bilateral or merely concentric, in the arrangement of the interior cells of the eight- or sixteen-celled groups is achieved it is at the expense of the bifid tips which appear, if at all, only as a broadening of the ends of the spine which hinders rather than helps the achievement of equal contact and pressure relations among the cells.

The whole *Pediastrum* group seems well calculated to show that fixed trends in development do not necessarily imply adaptation, though frequently resulting in highly specialized structural differentiations which are plainly adaptive from the standpoint of the life habits of the organism. Further, openness and lightness with increased surface in the colony as a whole is the same thing as deep lobing of its body for the single cell. But the development of a rounded least surface contour for a group of cells made up of the bipartition numbers 4, 8, 16, 32, etc., requiring an oblong form and perhaps favoring the lobing of the cells, is thus quite a different thing for them from the same tendency to round up expressed in their individual masses. In order to make a surface tension group under the given conditions the cells must lose in some degree their own tendency to assume the surface tension form and yet, as I have pointed out elsewhere ('18), this anomogenous condition imposed upon the cells in achieving their interrelations in the colony becomes then fixed in heredity so that the cell develops the characteristically lobed form even when as a result of accident it develops in almost complete freedom from contact and pressure relations with its sister cells.

I have referred to the interactions by which the type pattern of the colony is achieved as based on the polarities of the swarmspores and their sensitiveness to contact and pressure stimuli. That there can be no mosaic inheritance in the case of these colonies formed by groups of free-swimming zoöspores is, as I have pointed out before, sufficiently obvious. It is also clear that no spatially differentiated representation of the organization of the colony in the organization of the mother cell could have any bearing on the method of transmission of the type configuration of the colony. In *P. clathratum* both the colonies and the cells are bilaterally symmetrical, both show polar differentiation, the colony in one axis and the cell in at least two axes, and yet the polarity and bilateral symmetry of the cell are in no sense representative of the polarity and bilateral symmetry of the colony. Neither predetermines the other directly though there can be no question here that the cells as independent units build the colony and their properties determine its properties. Surface tension is a common factor in determining the form of the cells and through the adhesion of the cells to each other in determining the rounded outline of the colony as a whole, but as I have already pointed out it is the inherited anomogenous consistency of the cells which is of most significance in determining their form and it is their motility, polar differentiations, and sensitiveness to pressure and contact stimuli which make it possible for them to achieve the highly symmetrical and characteristic interrelations shown in the pattern of the adult colony. I am discussing elsewhere ('18) the possible relation of these contact and pressure interactions in the primitive ancestral cell group to the development of the form of the cells on the principle of functional hypertrophy. However it may be with this question, which involves the difficult problem of the inheritance of acquired characters, there can be no doubt that, as noted, in the species as one finds them the cell form in its major outlines is fixed by heredity and can be achieved by the cell when free and quite independent of pressure relations with other cells in the colony. That the typical cell form is developed to the extent that opportunity offers regardless of how the cell is placed in the colony is indicated by the perfection of the free lobe in one of the interior cells of the colony shown in FIGURE 18 and by the development of a fairly good spine on one of the interior cells of the colony shown in FIGURE 4. More extended evidence on this point is presented in connection with my study of *P. asperum* ('18).

It seems to me, further, clear that the functional polarity and the capacity of the cells to respond to pressure and contact stimuli are not fundamental properties present in full degree in the ancestral types of the group but that these characters have increased and become specialized with the gradual development of the highly modified and lobed form of the cells. Simple adhesion of the cells in a palmelloid mass may have been the initial stage in colony formation. Light reactions may have favored the development of the plate-like expanded form though this is achieved now by the polar differentiation and reactions of the swarm-spores quite independently of the direction of the light.

These reactions to pressure and contact and the resulting form determinations are typical examples of biogenetic processes in Hertwig's sense. It is quite possible that such reactions may be the determining factors in the root behavior which led Noll ('00) to assume morphaesthesia as a fundamental phase of morphogenetic behavior. Morphaesthesia is for Noll the expression of the capacity of lateral roots to regain a radial direction of growth after they have been forced out of it by an interposed obstacle—radial not to the point of origin of the root from the main axis but radial to the axis from the point at which the root becomes free from the obstacle. The capacity to regain such a generalized relation as that of the radius from any point of the axis opposite to which the root happens to be certainly implies a response to form-determining stimuli of the most delicate sort. Noll was inclined to regard it as a sort of direct reaction to the form of the whole organism by each of its parts. The only physical stimuli which seem to be involved are the pressure and contact interrelations involving weight relations, tensions due to bending, etc., between the cells themselves.

Whether or not such reactions are adequate to account for the radial growth of lateral roots with their much greater complexity of structure, there can be no question, it seems to me, that the assumption of a fundamental capacity to achieve symmetry is the natural suggestion from a study of the delicately balanced interrelations of the cells in such types as the sixteen-celled colonies of *P. clathratum* and the eight-celled ring-shaped colonies of *P. simplex*. Direct action of surface tension on the plastic though anomogenous cell bodies may account, as noted, for the final niceties of adjustment, but the grouping as first achieved by the free-swimming swarm-spores must be admitted to be a matter of cellular interactions and the major stimuli in such a series of adjustments must be contact and pressure. That chemotropism could play a rôle is hardly conceivable in view of the violent movements of the swarm-spores in the narrow confines of the mother vesicle. That in the last stages of swarming equilibrium should be reached in a situation of as nearly equal pressure and contact from all sides as is possible may seem to some to be merely a matter of physical necessity operating on what, from the conditions in the adult colony, might seem to be inert gelatinous four-lobed or one-spined masses, but in the fact that this equilibrium position is achieved by a group of freely swimming organisms, each with inherited cell-form tendencies which are certain to come to expression in greater or less degree, no matter how the cell is finally placed in the group, we find the proof that nothing less than the assumption of a capacity to respond to and maintain conditions of equilibrium when once achieved can adequately account for the symmetry of the typical colonies as we find them.

That the symmetrical spatial interrelations of the cells is no mere expression of the direct action of the physical principles of surface tension, adhesion, mutual pressure, etc., is further shown by the endless number of variations from the type configuration. There is good evidence here of trial and error by complex organisms with every type of error as well as degree of approximation to the typical fixed in the endless variations in detail which can be found in the configuration of the adult colonies. It is difficult to give an adequate picture of what one sees in watching the free-swimming swarm-spores darting here and there around and through the mass and the gradual appearance of order out of confusion with the coming to rest first of a peripheral series and then of the interior cells, but that cellular interactions of sensitive tropic units determine the symmetrical final configuration rather than the direct operations of surface tension, adhesion, etc., on the one hand or any mysterious controlling and adaptive principle of behavior seems to me the obvious suggestion from the facts. The evidence seems to me adequate for assuming a high degree of potency for such simple stimuli as contact and pressure between polarized cell units like those of *Pediastrum* in initiating and controlling morphogenetic processes.

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DETERMINATION OF ACIDITY IN PLANT TISSUES

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For many physiological purposes the determination of the concentration and amount of acids in plant juices is a matter of importance. Acid formation or acid splitting may affect the output of carbon dioxide and thereby alter the gas interchange relations. It is necessary to be informed as to the amount of its rise and decline to evaluate properly the energy-releasing processes connected with respiration. It is known also that the degree of acidity in an imbibed fluid has an important influence on the hydratative capacity of colloidal systems and therefore must affect the colloidal mélange of protoplasm. Besides this the concentration of acids in the vacuole has an important bearing upon the osmotic coefficient of its contents. Without attempting then to enumerate all the ways in which a knowledge of the acid content of plant juices may be of physiological importance, it is evident that the determination of this factor is necessary.

In this very brief communication it is not intended to give even a partial survey of the problem, or to touch upon the variety of methods which have been developed for the isolation of definite acids. For technical purposes many ways have been devised by which the acids in various fruits and other plant parts can be determined and extracted in a manner that is satisfactory for the results required. That these methods may not be applicable to some physiological problems is not a criticism of their technical value; but, at the same time, it is questionable in some instances whether the acids extracted really represent either in quantity or condition the acids originally present in the living cell.

In the first place, the manner of obtaining the plant juices may be considered. The common method is by pressure. As far as concentration is concerned, the juice squeezed out may represent with some accuracy the maximum concentration of the soluble substances present. Even here, however, there may be room for error. With the ordinary means at hand, pressure is not the easiest thing in the world to standardize and it is possible that identical samples might yield juices of slightly different concentration if subjected to different pressures. The speaker is quite aware that such errors may have crept into his own work, but feels rather confident from somewhat empirical tests that have been made that the error cannot be an important one.

Where, however, what may be termed total acidity is desired, a single pressure no matter how powerful opens the road to serious mistakes. By total acidity I mean the total acid content of a given weight of fresh or air-dry tissue. It is here that it is very difficult to tell in many published accounts how great have been the precautions not to leave a considerable percentage of acid in the rejected pulp. It is to be presumed that in most instances investigators were fully aware of this danger, but rarely is there any mention made of the procedure used to obviate the difficulty.

In his own work the writer has found that what appears to be a very close approximation of the actual total acid content may be obtained by repeated pressure. After the first juice had been expressed and the press released the remaining pulp is collected and copiously moistened with water, which it greedily absorbs. This is then pressed once more and the process repeated until the final expressed water shows by titration a practically negligible amount of acid.

All of the samples so obtained are mixed and made up to a definite volume, an aliquot portion of which is then titrated. In regard to the number of times this process is repeated each tissue will no doubt show its own peculiarities. In some very refractory tissues it might be an exceedingly difficult matter to satisfy oneself that the last trace of acid was extracted. In the tissues with which I have worked, notably the succulents, it has been found that the water which comes from the fourth pressing is nearly acid-free. Here again it is impossible to lay down a rule, for the type of press used might influence the result. Only by actual testing can we be sure that the acid is extracted.

By the method outlined we may obtain first a sample of pure juice to determine concentration and second the total amount of acid contained in a given weight of tissue. Where total acidity alone is required the speaker has used a simple method which is not in any way original but which by repeated test has been shown to be satisfactory and to yield very consistent results. Briefly the process is this. A small sample of the tissue is ground in a mortar with a little water and carefully washed silica sand. This is then strained through glass wool: the pulp and wool are again ground and strained and if there is evidence that the tissue is not finely enough comminuted by this time the process is repeated. The various samples are then mixed together and filtered into a graduated flask, care being taken to wash the filter thoroughly. An aliquot portion of the known volume is titrated as usual. Before finally rejecting the pulp it should be tested to determine if it is acid-free. This process may be carried on with considerable speed and the whole determination may be completed within fifteen minutes of the time of taking the sample. Time may also be gained by the use of a centrifuge in place of the filtering.

One thing, perhaps, is evident in the methods outlined, that is, the quickness with which the processes may be carried on, and it is on this point I wish to lay especial stress. We know that the organic acids with which we are dealing in plants are in many cases highly unstable and that if considerable time elapses between their extraction and estimation changes may occur that will influence the final result. Also the acids are easily affected by any substances that may be added to the solutions. Consequently, it is requisite to titrate the juices as soon as possible and in as nearly their original condition as possible in order to obtain results that are significant from a physiological standpoint. It is in these regards that many of the methods commonly employed, no matter how useful they may be for some purposes, are not always available for the study of the activities of the living organism. For instance, the addition of alcohol, while it may serve to clear the juice for the purposes of titration, must undoubtedly produce the esterification of some part of the acids. Similarly other chemical substances will not be without their effect in altering the original acidity. Besides all this, the time which must elapse in the many filterings and extractions may allow a chance for partial disorganization of the unstabler acids.

These considerations have influenced the writer in his own work to sacrifice the clearness of the solution to be titrated for rapidity of estimation. It is true that from the standpoint of the chemist the extracts procured are often cloudy and colored so that the end point is not so sharp as it would be in a clearer solution but by the use of rather greater quantities of the indicator than usual and by accustoming the eye to the behavior of the specific plant juice it is probable that the results obtained are more nearly accurate than by a method which in the chemical sense may be more perfect. I am fully aware of the various objections which the chemist may bring to the procedures as outlined, and I admit their inadequacies. For the purposes desired, however, they are more suitable than more elaborate ones.

The two greatest difficulties are, first in the color of the solutions and second in the precipitation of protein substances when the neutrality point is approached. For the first there is at present no very good remedy to be suggested. By the selection of an indicator the color change of which is compatible with observation in an already colored solution, something may be done. The color change of the juice often suggests itself as an indicator and if one were certain of the neutrality of its end point it could be used instead of an indicator. As to the flocculation of colloidal substances on the approach of the neutral point it may be said that the precipitate is usually white and does not interfere as much with the color reaction as might be supposed. Of course in separating out the protein may adsorb some acid, but since the precipitate does not appear until the solution is nearly neutral the amount so occluded cannot be large. The addition of substances like bone-black for clearing and decolorization is tempting but open to various objections, the most important of which is that the bone-black may itself adsorb acids.

The writer would welcome the suggestion of improvements in the procedures outlined, particularly in the matter of a satisfactory method of obtaining a perfectly clear and colorless extract for titration purposes. It so happens that the plants which I have especially been investigating yield juices which are usually fairly colorless and which contain only a small amount of colloidal substances which flocculate out in a neutral solution. The last method outlined was used, with considerable success, during the summer of 1917 at Carmel, California, when the acidity of a number of types of the local plants was determined in addition to that of the succulent forms which were being investigated in detail. The results were interesting, but too few in number to warrant publication at this time.

SIX MISUNDERSTOOD SPECIES OF AMANITA*

BY GEORGE F. ATKINSON

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Recent monographs of the Amanitas have not lessened the obstacles in the way of recognizing the species of this difficult genus. On the contrary, they have introduced certain elements of confusion. This is evidenced by a compression of the number of species in regions where there has not been an opportunity of studying living plants but only dried material has been examined. In quite restricted localities where intensive studies have been made there has occurred a lively splitting process resulting in the multiplication of species based to some extent on trivial characters, the result of environmental and growth influence. I wish here to call attention to several of the species which have been misunderstood.

Among the pure white Amanitas in the eastern United States there is one species which is easily recognized from all the others usually on sight, but with certainty after a microscopic examination. This is *Amanita bisporigera*.† It is a species with a white volva with apical dehiscence and a prominent limb. The pileus is smooth, viscid, and glistening white. The stem is pure white and slender. The basidia are constantly two-spored. The spores are globose or subglobose.

Its nearest ally is a similar white species with four globose spores to a basidium. This four-spored species is a robust plant, interpreted in this country by some as *Amanita verna*, by others as a white form of *A. phalloides*.‡ *Amanita bisporigera* is dis-

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* Illustrated by lantern slides.

† *Amanita bisporigera* Atkinson. Bot. Gaz. **41**: 348. 1906.

‡ *Amanita bisporigera* is placed in *Amanita phalloides* by Murrill (Mycologia 4: 240. 1912; and N. Am. Fl. **10**: 70. 1914), although very different from the typical *Amanita phalloides* of Europe. Coker (Coker, W. C., The Amanitas of the Eastern United States. Jour. Elisha Mitchell Sci. Soc. **33**: 1–88. *pl. 1–69.* 1917) places *Amanita bisporigera* as a synonym of *Amanita "verna."* This four-spored white *Amanita* of North America was also interpreted by me as *Amanita verna* (see

tinguished from the robust, white, 4-spored species, not only by its 2-spored basidia, but by its more slender form. In nearly all cases one can distinguish it by size alone from small forms of the robust, 4-spored species, without a microscopic examination. However, in several hundred specimens I have examined during the last ten or more years I have not found a single case of a variation in the 2-spored character of the basidia. It is a very distinct genetic type and represents a good species. This interpretation is reinforced by the fact that, in several of the genera of the agarics, there are a number of constantly 2-spored species.

Another species, *Amanita cothurnata*,* is interpreted by some as specifically identical with *Amanita pantherina*.† *Amanita cothurnata* is entirely white, or, rarely, in some individuals there is a tinge of umber over the center of the pileus, or now and then individuals are found with a slight tinge of yellow at the center. The volva is circumscissile in both species. The white calyptra is torn into small floccose patches which are distributed quite regularly over the surface of the pileus. In *Amanita pantherina* the pileus is a dark smoky brown, and these white patches on the dark background are suggestive of the spotted appearance of the panther, whence the name *pantherina*. The lower part of the volva in both species is "cothurnate" or "booted" concrete with the stem, the "limb" in *Amanita cothurnata* terminating in a thick, regular shoulder or roll, like the top of a closely fitting buskin. This species differs from *Amanita pantherina* chiefly in its color, and in its more slender habit, as can be seen from these lantern-slide reproductions of photographs.

At maturity the granular content of the oval, or short-ellipsoid spores usually disappears and is replaced by a large globose oil drop of about the same dimensions as the transverse diameter of the spore. This large glistening oil drop is very distinct in contrast with the nearly transparent, thin, spore wall, which is rather

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Studies of Am. Fungi, Mushrooms, Edible, etc., 1st edition, p. 60. *f. 59.* 1900; 2d ed. 1901). It is, however, quite different from the *Amanita verna* of France (*Agaricus vernus* Fr. ex Bull. Champ. Fr. *pl. 108*) as I have found from specimens since collected in France.

* *Amanita cothurnata* Atkinson, Stud. Am. Fungi, Mushrooms, etc., 1st edition, p. 66. *f. 68, 69.* 1900; 2d ed. 1901.

† Coker, W. C. Jour. Elisha Mitchell Sci. Soc. **33**: 46. 1917.

difficult to see. In specimens of *Amanita pantherina*, which I have collected in the Jura mountains in France,* the spores at maturity, or in dried plants, still retain the granular content. This condition, however, may possibly vary in some specimens, and the presence or absence of an oil drop in the spores, may not be so important a specific character as is usually assumed. But it is worthy of note that in all specimens of *Amanita cothurnata* which I have examined, this change in the spore has taken place. Another witness of the specific distinction of *Amanita cothurnata* is its wide distribution, comparative abundance, and constancy in character, while typical *Amanita pantherina* is quite rare in this country according to my observations. Some of the few individuals which I have found of this species in the United States raise some doubt as to their specific identity with *Amanita pantherina* of Europe, and resemble strongly in some respects another American species, *Amanita velatipes*. Since the latter species is interpreted by one student as synonymous with *Amanita baccata* of Europe, it is readily seen to what an end such indiscriminate "lumping" would lead.

Several other American species have recently† been added as synonyms to quite a long array of names of European forms, cumulatively assembled under *Amanita jonquillea* Quelet and *Amanita baccata* Fr. I will discuss here only two of these, which are not only specifically distinct from each other, but also from *Amanita jonquillea*. These are *Amanitopsis albocreata*,‡ and *Amanita velatipes*.§

Amanitopsis albocreata is a white species with now and then individuals showing a yellowish tint over the center of the pileus, which is striate on the margin. The annulus is absent. The volva is circumscissile, the calyptra forming white floccose patches on the pileus, much as in *Amanita cothurnata* and *Amanita pantherina*. The lower part of the volva is ocreate, concrete with the base of the stem and fits it like the legging of a boot, but it is not so prominent, nor does it extend so high up on the stem as is usual

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* In 1905. The determination was confirmed by E. Boudier.

† See Coker, W. C. Jour. Elisha Mitchell Sci. Soc. **33**: 1–88. 1917.

‡ *Amanitopsis albocreata* Atkinson, Jour. Mycol. **8**: 111. 1902.

§ *Amanita velatipes* Atkinson, Stud. Am. Fungi, Mushrooms, etc. 1st edition, p. 63. *f. 64–67*. 1900; 2d ed. 1901.

in *Amanita cothurnata*. Sometimes a portion of the thin marginal area of the calyptra may adhere to the rim of the ocrea, and thus resemble the volva limb of *Amanita jonquillea*, which is not ocreate but sheathing. In the latter species the volva is partly circumscissile and partly apical in its dehiscence. The volva is thin and weak. A portion of the calyptra margin remains at the base as a thin, free, sheathing limb, while the remaining portion rests on the pileus in the form of floccose patches. But the essentially differential feature in respect to the volva here is that the lower portion is not ocreate as it is in *Amanitopsis albocreata*. This feature can be seen in the lantern views presented here, from photographs of *Amanita jonquillea* which I made from specimens collected by me in the Maritime Alps, at Berre-des-Alpes, near Nice, in 1905 and also in 1910. The pileus of *Amanita jonquillea* is pale yellow, about the color of jonquils, and the margin is striate. The spores of *Amanitopsis albocreata* are globose to subglobose, while those of *Amanita jonquillea* are ellipsoid, as shown in these reproductions from photomicrographs of the spores.

A thin partial veil and an annulus are present in *Amanita jonquillea*. The veil is quite thin and sometimes it is so torn during the expansion of the plant that a distinct annulus is not present. In rare cases a delicate annulus may be present in *Amanitopsis albocreata*. But in my numerous collections of this species I have not observed one. However, in all species of *Amanitopsis* which I have studied in the fresh state, the ground tissue is present, which, in many species of *Amanita* at least, forms the partial veil and annulus. This has been demonstrated in *Amanitopsis vaginata* through a study of the development of this species.* As I pointed out at that time, the distinction between the genera *Amanita* and *Amanitopsis* is probably not a natural one. There are several species of *Amanita* (and *Amanitopsis* also) in which the presence of an annulus is variable. The ground tissue forming the partial veil, though sometimes abundant, possesses a very low degree of coherence, with the result that sometimes an ephemeral annulus is present and at other times it is absent. The facts that a distinct annulus is sometimes wanting

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* Atkinson, G. F. The development of *Amanitopsis vaginata*. Ann. Myc. **12**: 369–392. *pl. 17–19*. 1914.

in *Amanita jonquillea*, that there is a tinge of yellow in the pileus of some individuals of *Amanitopsis albocreata*, with variability in some of the other characters, are responsible for the opinion expressed as to the specific identity of these two species. Each species has its own range of fluctuating variation. The fact that at the extremes of the range of fluctuating variation one or more of the characters in different species overlap is not evidence of their specific identity.

Now we come to *Amanita velatipes*, another species which is confused with *Amanita jonquillea et al.* This is a large and robust species, about equal in size to *Amanita muscaria*. The pileus is usually hair-brown, or umber-brown, sometimes with a tinge of lemon-yellow, or rarely entirely maize-yellow. The remaining parts are white. The volva is thick and distinctly circumscissile. The calyptra breaks into concentric rings, especially near the margin, and these transversely into irregular areolate patches, which are usually firm and compact. They are easily freed from the viscid pileus and commonly warp up around the edge and may thus soon fall away. The lower portion of the volva remains concrete with the base of the stipe and is often ocreate. But more commonly the continued elongation of the stem severs it once or twice more in a circumscissile manner, thus leaving one or two stout rings above the bulb. These rings are more rarely checked transversely into coarse warts, in robust specimens, approaching then the usual condition in *Amanita muscaria*. The partial veil is ample and adheres very firmly to the stipe. It is easily freed from the gills but clings firmly to the margin of the pileus, for a time, and as the plant expands the veil is ripped off the surface of the stipe and forms an inferior or median annulus. The spores are oboval and inequilateral in profile, and when mature contain a large oil drop.

It is difficult to understand a concept of species which would unite *Amanita velatipes* with *Amanita jonquillea*. Its relationships are far closer to *Amanita pantherina* and *Amanita muscaria*. The smaller forms are exceedingly difficult to distinguish from *Amanita pantherina*. Or, shall we say that large forms of *Amanita pantherina* are difficult to distinguish from *Amanita velatipes?* I have several times collected, in the vicinity of Ithaca, a large white *Amanita* which might be taken for a white form of either

Amanita velatipes or *Amanita muscaria*, If *Amanita velatipes* is synonymous with *Amanita jonquillea*, then *Amanita muscaria* and *Amanita pantherina* must be thrown into the same "melting pot"!

Two more species remain to be discussed at this time, which have been misunderstood, and consequently united, in the two recent treatments of the Amanitas in this country. These are *Amanita Frostiana* and *Amanita flavoconia*.*

Amanita Frostiana† is a beautiful species described by Peck in 1883. This description is brief but very accurate and illustrates in a striking manner not only Dr. Peck's powers of observation, but his critical and analytical mind. It is a rather unique procedure, in a work of a monographic nature, in writing a diagnosis of *Amanita Frostiana*, to ignore this original description by Peck, and as it appears, leave out of consideration altogether any individuals which represent this species, and deliberately draw up a description of *Amanita Frostiana* from individuals recognized as *Amanita flavoconia*, a very different species.‡ *Amanita Frostiana* is a small to medium-sized plant. The pileus is orange or yellow, and distinctly striate on the margin. The volva is circumscissile in dehiscence. The calyptra is separated into numerous floccose patches on the surface of the pileus. The lower part of the volva is ocreate. The stem and partial veil are yellow. The spores are distinctly globose.

Amanita flavoconia§ is also a small to medium-sized species. The colors are much as in *Amanita Frostiana*. But it differs from *Frostiana* in its *smooth, not striate* pileus, in its smaller, oboval to subellipsoid spores, and in its volva *all friable*. The lower portion of the volva, that which remains over the base of the stem, is in the form of a fine yellow powder, with not the slightest suggestion of an ocrea. The lower part of the stem broadens gradually to the bulb, except in rare cases when, under certain unfavorable environmental conditions, somewhat depauperate forms may result, in which the transition from the stem to the bulb is abrupt.

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* See Murrill, W. A. Mycologia **5**: 76. 1913, and N. Am. Fl. **10**: 74. 1914. Coker, W. C. Jour. Elisha Mitchell Sci. Soc. **33**: 65. 1917.

† *Agaricus Frostianus* Peck, N. Y. State Cab. Nat. Hist. **23**: 69. 1872.

‡ See Coker, W. C. Jour. Elisha Mitchell Sci. Soc. **33**: 65. 1917. But it is quite possible his specimens were not typical *flavoconia*, but belong to a different species.

§ *Amanita flavoconia* Atkinson, Jour. Myc. **8**: 110. 1902.

But even under these conditions there is no evidence of an ocreate volva. Moisture frequently holds portions of the calyptra in definite patches, but its texture is different from that of the volva in *A. Frostiana.* In very rare cases, when the weather conditions are somewhat drying, the margin of the pileus may be slightly striate, as sometimes occurs with thin pilei, which normally are not striate. But this rarely appearing striate margin in *Amanita flavoconia* is one of the extreme limits of its range of fluctuating variation, not at all an indication of its specific identity with a normally and regularly striate species. But aside from this feature, the very different spores, and volva, separate *flavoconia* very clearly from *Frostiana.* It is more closely related to *Amanita muscaria*, or the form sometimes called *formosa.*

For a number of years, before I made a critical study of *Amanita flavoconia*, I regarded the specimens of this species which I encountered as belonging to *Amanita Frostiana.* I remember that in 1902, when collecting and studying fungi for a week, in company with Dr. Peck in the vicinity of Lake Piseco, in the Adirondack mountains, I showed him some specimens which I had collected during the morning, and said: "Here is an undescribed species of *Amanita.*" He examined the specimens critically for a few minutes and then said: "Yes, it is. Heretofore I have taken it for *Amanita Frostiana.*" *Amanita flavoconia* appears to have a much wider distribution than *Amanita Frostiana* has. It is very common in the Adirondacks; in fact, it appears to be the most common species of *Amanita* in that region, while I have never found *Amanita Frostiana* there, though it is not uncommon in the Cayuga region, and probably in all of central and western New York.

The range of fluctuating variation presented by some of the characters of these, and many other species of *Amanita*, is such that one extreme of the range in a species may now and then show a tendency toward the constant character of the corresponding structure in a related species. In this way the ranges of fluctuating variations are linked by this touch, or slight overlapping, of the extremes of all the species. If this relation of the ranges of fluctuating variation, between the different species of *Amanita*, is interpreted as indicating specific identity, it would result in reducing all the *Amanitas* to a single species.

SOME OBSERVATIONS ON THE DEVELOPMENT OF PERIDERMIUM CEREBRUM

By B. O. Dodge and J. F. Adams

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(with plates 4–6)

The form of *Peridermium Cerebrum* Peck on *Pinus rigida* in the vicinity of Lakehurst, and Toms River, New Jersey, has presented several points of interest. Specimens of this fungus on *P. virginiana* from Bedford, Virginia, have been available for comparison through the kindness of Professor R. A. Harper.

The prevailing type of infection observed in New Jersey appears as circular or elongated canker-like swellings on trunks ranging up to eighteen inches in diameter. Where suckers developed after trees had been cut down, the recent infections appear as globular or fusiform swellings. The canker-like swellings on the trunk are the common form of the fungus. Infections are frequently found at the base of the tree as well as at varying heights on the trunk, usually below the region bearing branches. The trunk infections often consist of a number of closely associated swellings, the outermost being smaller and younger developments. The galls vary in size and are circular or elliptical in outline. This difference in the shape of the swellings suggests that the infection may sometimes progress more rapidly in one direction than in the other. Stewart,* studying the globoid galls of *P. Cerebrum* on *Pinus Banksiana*, is of the opinion that the fungus spreads quite as slowly vertically as it does horizontally. In several cases at Lakehurst protuberant elongated swellings were found developing parallel with the trunk, and were at least six times as long as they were wide. On the other hand, the invasion of the host by the fungus is sometimes more rapid peripherally than it is vertically. The disease in this material obviously

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* Stewart, A. Notes on the anatomy of *Peridermium* galls. Am. Jour. Bot. 3: 12–22. 1916.

progresses by the development of secondary ovoid slightly protuberant galls, so that very often at least half of the trunk is girdled. The more central swellings, when they are closely associated, are usually dead. The whole trunk is slightly bent at this point. This bending is due to the inhibition of growth and the death and decay of the region of original infection. The typical condition is that of death at the center and proliferation at the margin. In many cases the entire affected area is dead, owing to the action of such agencies as fire, insects, and birds. Borer and woodpecker injuries in several instances were found to be the cause of the death of the swellings. Weir* has reported that borers and wood-rotting fungi, entering the burls on *Pinus divaricata*, often hasten the decline of the tree.

While the individual swellings or galls may be circular or elliptical in outline, the total or final effect of the parasite on the host sometimes is such as to bring about a fusiform enlargement of the trunk. An example of this type of infection is shown in PLATE 4, FIG. 2, which is from a photograph of a tree at Lakehurst. The infected area is about five feet from the base of the tree. At the widest part of the swelling the trunk is about eighteen inches in diameter and tapers from this region so that the diameter is about four inches less at the limits of the swollen region. Viewed from the side this tree is seen to be bent or "kneed" in the manner shown in PLATE 5, FIG. 1. This figure is from a photograph of another infected tree from the same region. There are at least ten separate swellings on the canker shown in PLATE 4, FIG. 2. These were outlined with ink on the photograph so that their limits may be made out more distinctly in the reproduction. If we assume that the whole canker is the result of one primary infection and that the point of infection is now shown by the presence of the oldest dead gall shown at the center of the picture, we see how the fungus has spread in all directions. There is no bark on this central gall and the exposed wood is dried and cracked. The second gall, just at the right, is somewhat smaller and circular in outline. This gall is also dead. Above the central gall is a large ovoid one that is dead, but not in the advanced stages of decay. At the right and left in this top row of swellings are

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* Weir, J. R. Observations on the pathology of the jack pine. U. S. Dept. Agr. Bull. 212: 1–10. 1915.

two living galls, the smaller of which is producing aecidiospores. The larger one at the left was covered with a thick mass of pitch at this time. On the lower parts of the infected region are five or six other galls, the larger one being dead while the others are alive.

The question as to the manner in which the fungus comes to attack new regions is an interesting one in view of the fact that we have these separate galls, all evidently resulting from one primary infection. The spread of the mycelium appears not to be by gradual encroachment but rather by sudden migration induced by the conditions that are to bring about or have already brought on the death of the tissues of the gall. Some light may be thrown on this question by a study of the specimen figured in PLATE 5, FIG. 1, which is a side view of a portion of a tree ten inches in diameter at the cankered region. The marginal gall (at the right in the picture) is alive, but the other two, both furrowed and denuded, are in advanced stages of decay. A cross section of this same specimen is shown in PLATE 6. The tree was plainly infected when it was very young, evidently in the growing region of the stem at a point about two feet from the ground. The wedge-shaped abnormal discolored gall-tissue can be traced to within three or four rings of the center. By splitting the central wedge we find that, further down, the infected area approaches the very center of the tree. The first gall growth has entirely disappeared, owing to decay. The fungus has spread peripherally by a series of sudden localized migrations. At the right (above) the first migration occurred about the tenth year, and about the fourteenth year at the right-center (below). Both migrations resulted in the formation of large, lobed or furrowed galls, the wood of which is now discolored and decayed. Just when the other migrations took place is difficult to determine. At the upper left corner a distortion of the annual ring is evident at about the twenty-sixth year. At the lower left, the wedge-shaped band of solid, dark-colored wood begins with the eighteenth year and spreads out gradually for eight years more before this section shows the beginning of the globoid gall. It has evidently taken nine years for the upper swelling at the left to develop, although the larger amount of the characteristic gall tissue has been formed during the last three years.

Infections sometimes occur at the base of a tree, as shown in PLATE 5, FIG. 2. This infection has spread peripherally very rapidly. The dark area, at the right of the center, is dead, but the bark still adheres. The other lobes of the gall are producing aecidiospores.

The prevailing type of trunk infection on *P. rigida* in the pine barrens of New Jersey is interesting when compared with those observed by Weir (*l. c.*) on *P. divaricata*. He points out that *Peridermium Cerebrum* in dry sandy areas confines itself more generally to the branches, occurring more rarely on the trunk. In the pine barrens the older swellings are very rough in appearance. Several layers of loose scaly bark are usually found adhering. This is the tissue that is sloughed off after the development of spermogonia or aecidia. It adheres most strongly at the margin of the infected areas. The outer younger swellings possess a smooth tan-colored layer of cork tissue.

In cross sections of the trunk the dark wood of infected areas contrasts so markedly with the healthy wood that the time at which infection took place can be determined fairly accurately. In eight trees that were cut where the disease was restricted to the trunk, it was found that infection had occurred when the trees were from one to four years of age. Cross sections of typical globoid galls on *P. virginiana* from Bedford, Virginia, show that infection usually takes place during the first year's growth. Stewart (*l. c.*) has stated that infection on *P. Banksiana* usually, if not always, occurs during the first year's growth of the branch. Where it is possible to trace the annual rings of growth in *P. rigida* through the infected and uninfected regions, it is found that about twice as much wood is formed in the diseased region as in the healthy.

The mycelium is uninucleated and its intercellular development is abundant in the cortex. The hyphae appear to follow the medullary rays in the cortex as well as in the wood where the mycelium is more sparingly developed.

Haustoria are commonly developed in the cells of the medullary rays. They are not exceptionally large and have the usual constriction where the cell wall is penetrated. They are of about the same diameter as the hyphae from which they originate and are sometimes found to be adjacent to the nucleus. Occasionally two or three haustoria are found in the same cell. The cells of the cortex are not attacked by haustoria as frequently as are those of the phloëm and medullary rays. Living hyphae with haustoria are found in wood tissue several years old.

We were not fortunate enough to observe the exudation of spermatia in the New Jersey material. Sections of material showed the presence of spermatiophores bearing spermatia as early as March 25. They form a palisade layer that appears to be spread over indefinite areas of considerable extent like a caeoma type of fructification. This palisade is formed beneath four or more layers of newly developed cork cells. The spermatiophore primordium consists of a compact mass of uninucleated cells of mycelium situated just above the outer row of cortical parenchyma cells. Below this the mycelium is sparingly developed as compared with what we find below the aecidium primordium. The Virginia material was more favorable for the study of the spermatial layer. This material consists of the typical globoid swellings as described by most investigators of *P. Cerebrum*. The galls are fairly smooth in appearance compared with the New Jersey material. The development of the palisade layer of spermatiophores bearing spermatia was first observed in sections of material collected February 9. The primordium develops between the cortex and the cork layer as shown in TEXT-FIGURE I. The overlying cork layer is smooth in appearance. Specimens were placed in moist chambers and within twenty-four hours exudations of spermatia appeared. The cork becomes irregularly cracked so that the spermatia exude in yellowish droplets. There is no special aperture through the bark for the escape of the spermatia; they ooze out as sticky exudations through cracks naturally formed by the growth of the gall. On removing the overlying cork a yellowish crust-like layer of spermatiophores is exposed.

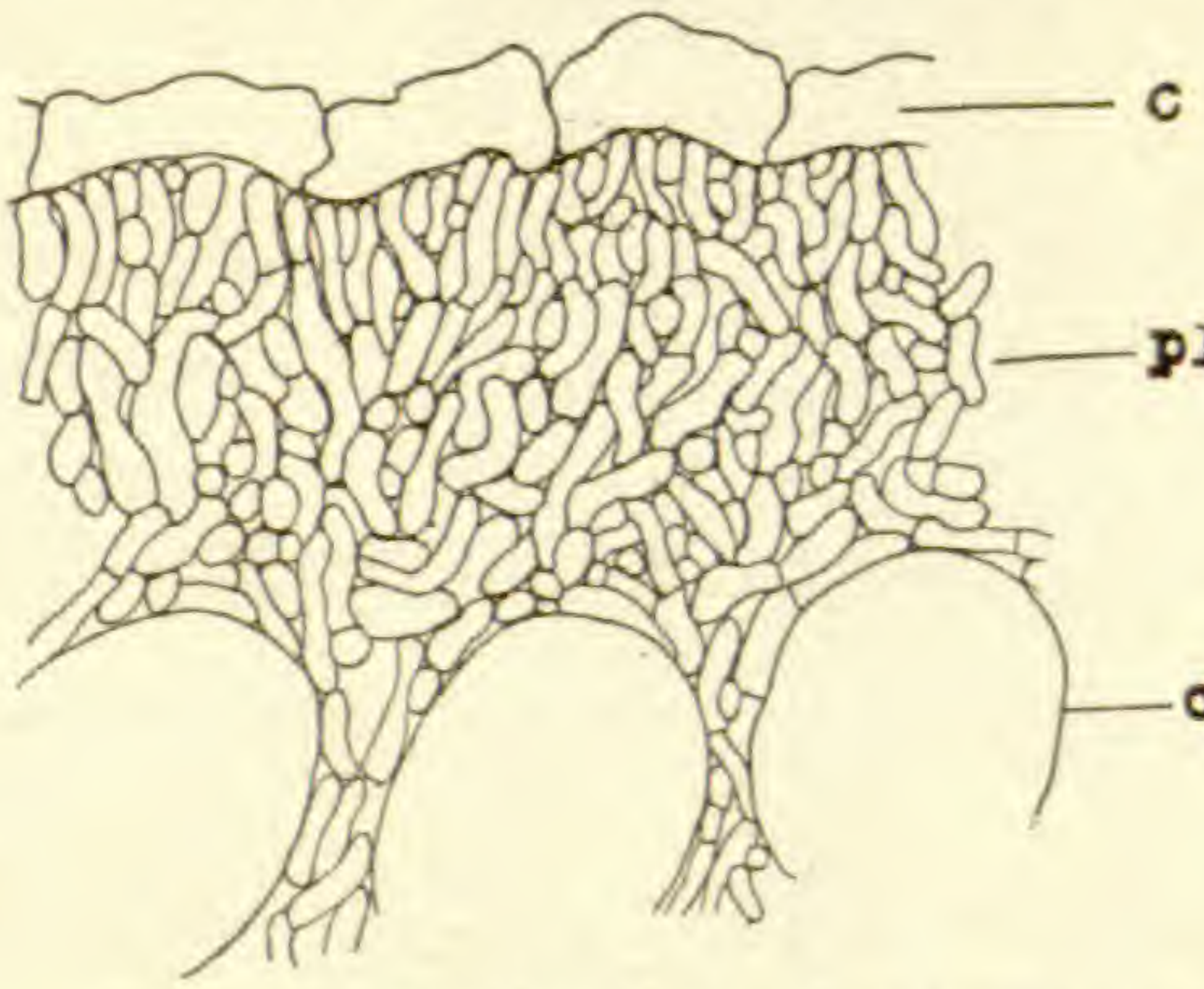

FIG. 1. Section through spermogonial primordium. *c*, cork; *pl*, plectenchyma; *cp*, cortical parenchyma.

This layer is continuous over the gall except where interrupted by small irregular patches or strips of cork that can not be removed easily. A burl with portions of the cork removed is shown in PLATE 4, FIG. 1. The irregular patches of thin cork are outlined to bring out by contrast the smooth, shining spermatiophore surface. A continuous area half an inch square can frequently be uncovered, disclosing the crust-like spermatial surface. Microtome sections three quarters of an inch long have been made, showing a continuous palisade layer. A small portion of a section through a matured spermatial layer is shown in TEXT-FIGURE 2. We have not observed in our sections that this effused palisade of spermatiophores is limited by a definite marginal system of sterile cells. Spermatial primordia frequently extend from the margin of matured areas as a plectenchyma of hyphae between the cork and cortical parenchyma as illustrated in TEXT-FIGURE 1. The cortical cells immediately below the layer of spermatiophores are not spread apart by the hyphae as conspicuously as are those below the aecidium. We have not seen in any instance spermatial hyphae developing in the tissue overlying that in which the aecidia are being formed. Cross sections of the Virginia material developing both spermatial and aecidial fructifications on the same gall show that there is no sharp line of demarcation between the two. In one burl there was a space of only 700 μ separating them. The nature of the spermogonia of *P. Cerebrum*

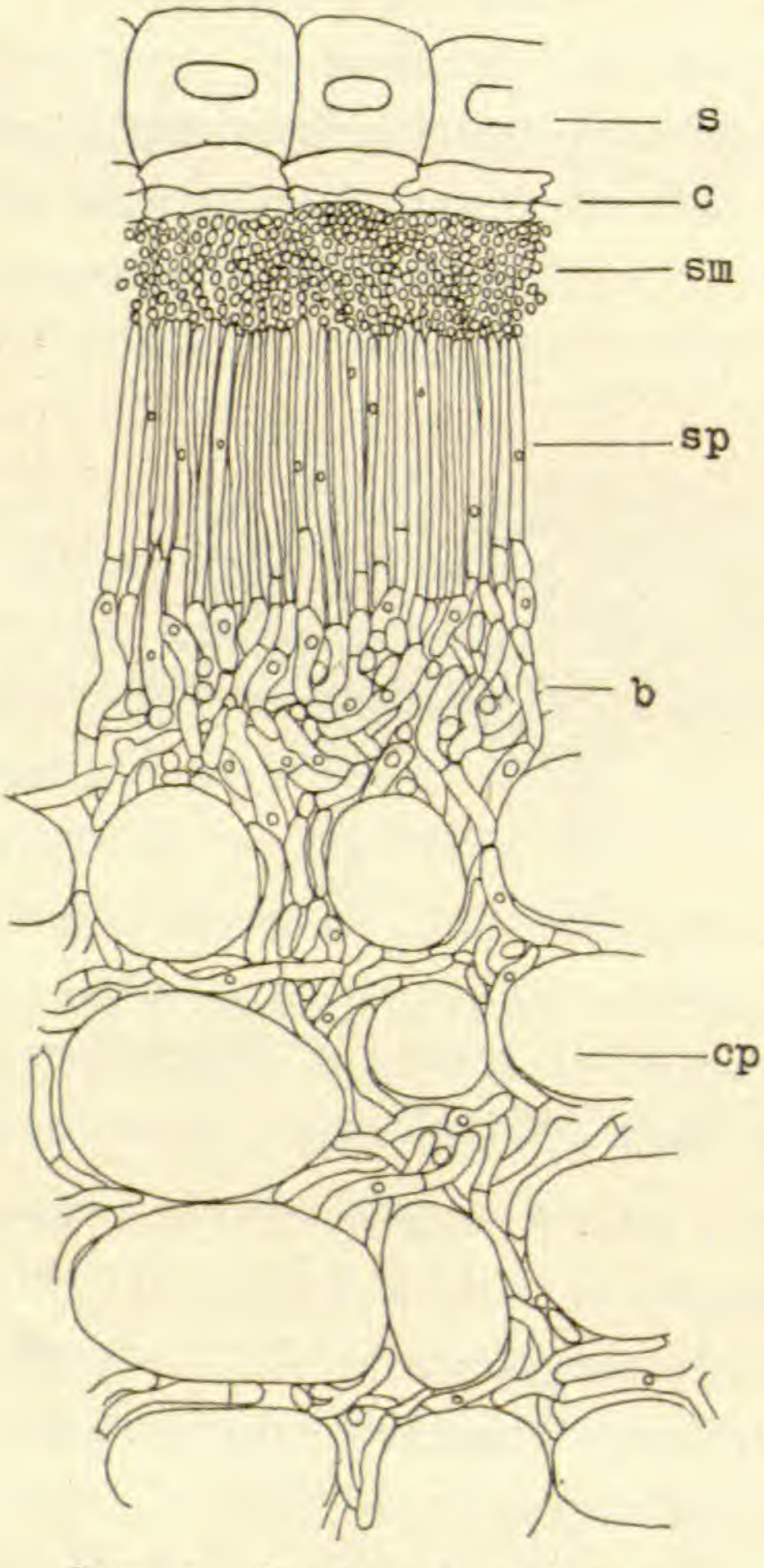

FIG. 2. Section through the cortex showing the spermatial layer. *s*, sclerenchyma; *c*, cork; *sm*, spermatia; *sp*, spermatiophores; *b*, basal tissue; *cp*, cortical parenchyma.

has been noted by Arthur and Kern* and others. We find that the spermogonia are not definitely delimited units. The spermatia are developed from an extensive palisade layer of spermatiophores spreading out indefinitely over the surface of the gall, thus producing a typical caeoma-like structure. Our conception of the meaning of the terms spermogonium and pycnium must be broadened if we are to use either of them in describing this structure.

In the New Jersey material it has not been possible to determine with accuracy very long in advance those swellings which will develop aecidia. The tissue in which aecidia are developed is usually sloughed off by the following spring. It appears as a dry corky layer, the surface of which possesses the cerebroid outline, due to the aecidial scars. The aecidium primordium has been observed in cross sections of material as early as April 29. At this time it appears as an extensive, deep-seated yellowish layer in the cortex, where it can be easily recognized. The cells of the cortex in the region of the primordium are conspicuously separated by the abundant development of the vegetative mycelium. The outer two or three rows of cortical parenchyma cells are pushed outward by the primordium. The relation of the primordium to the host tissue may best be understood by referring to TEXT-FIGURE 3. This figure is drawn from a section of the cortex in

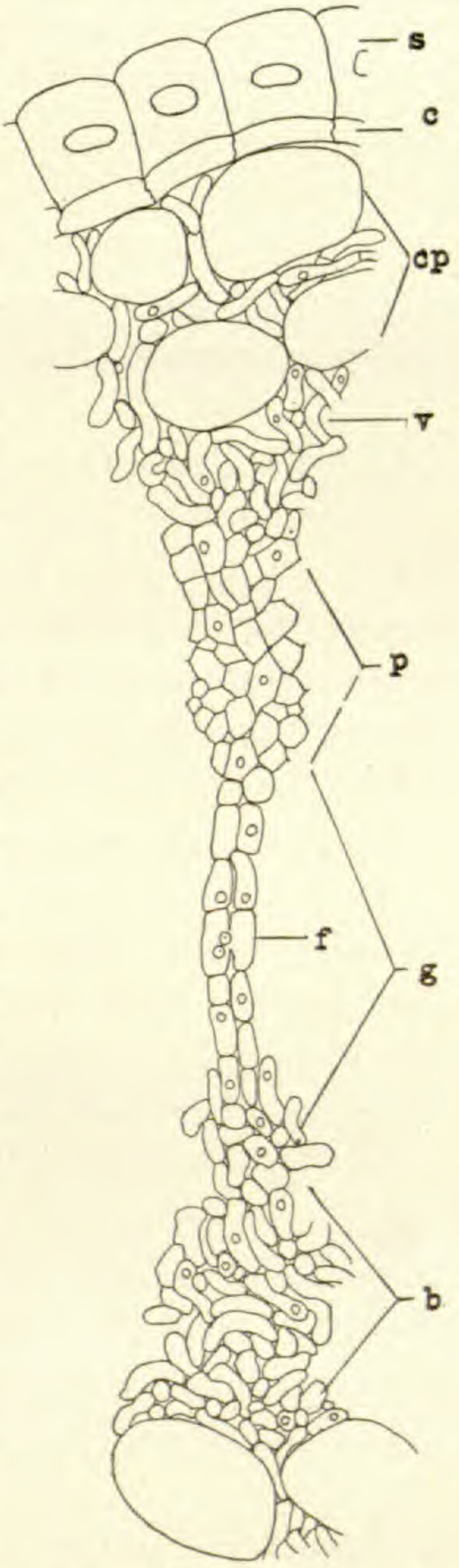

FIG. 3. Section through aecidium primordium from material collected at Bedford, Virginia. *s*, sclerenchyma; *c*, cork; *cp*, cortical parenchyma; *v*, vegetative hyphae; *p*, pseudoparenchyma; *g*, gametophoric hyphae; *f*, fusion cells; *b*, basal tissue.

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* Arthur, J. C., & Kern, F. D. North American species of *Peridermium* on pine. Mycologia **6**: 109–138. 1914.

which the primordium is developed. Only two rows of overlying cortical parenchyma cells are shown in this section. The number, however, varies and there may be as many as four or five layers. Above these outer parenchyma cells (*cp*) there are from one to four layers of flat, thin-walled cells (*c*) and beyond these one to four layers of large sclerenchyma cells (*s*). At the base of the primordium there is a compact mass of interwoven hyphae (*b*) from which parallel rows of cells originate. These are the gametophoric hyphae (*g*) which are eight or more cells in length. The fusion cells (*f*) in these chains are recognized by their being deeply stained in the preparations. Beyond the gametophoric hyphae, in this stage, we find a considerable development of pseudoparenchyma (*p*). Above the pseudoparenchyma the vegetative hyphae (*v*) are shown pushing in between the cells of the outer layers of cortical parenchyma (*cp*). The aecidium has its origin slightly deeper than the spermogonium. In the spring of 1916 at Lakehurst, N. J., the matured aecidia were first observed on May 21.

In no instance have we discovered spermogonia and aecidia following each other on identical areas of the same gall. Certain galls were found developing only aecidia, others only spermatia. In the Virginia material it was found in several instances that both developed on different parts of the same gall. This would indicate there is an alternation of the aecidium and spermogonium as reported by Hedgcock and Long* and others. In the large canker-like swellings of the New Jersey material we have not found galls bearing both aecidiospore and spermatia galls. We have found a few cases of infection on *P. rigida* in New Jersey with the swellings still bearing the rough, scaly bark showing plainly aecidial scars in April. When this was removed we found directly beneath, separated from it by a few layers of new cork, aecidium primordia. This may have been due to the possibility that the old cork layers were not shed the previous year, that is, at the time spermatia were developed.

Seedling oaks of *Quercus ilicifolia* and *Q. marilandica* were found near Lakehurst, New Jersey, with mature uredosori as early

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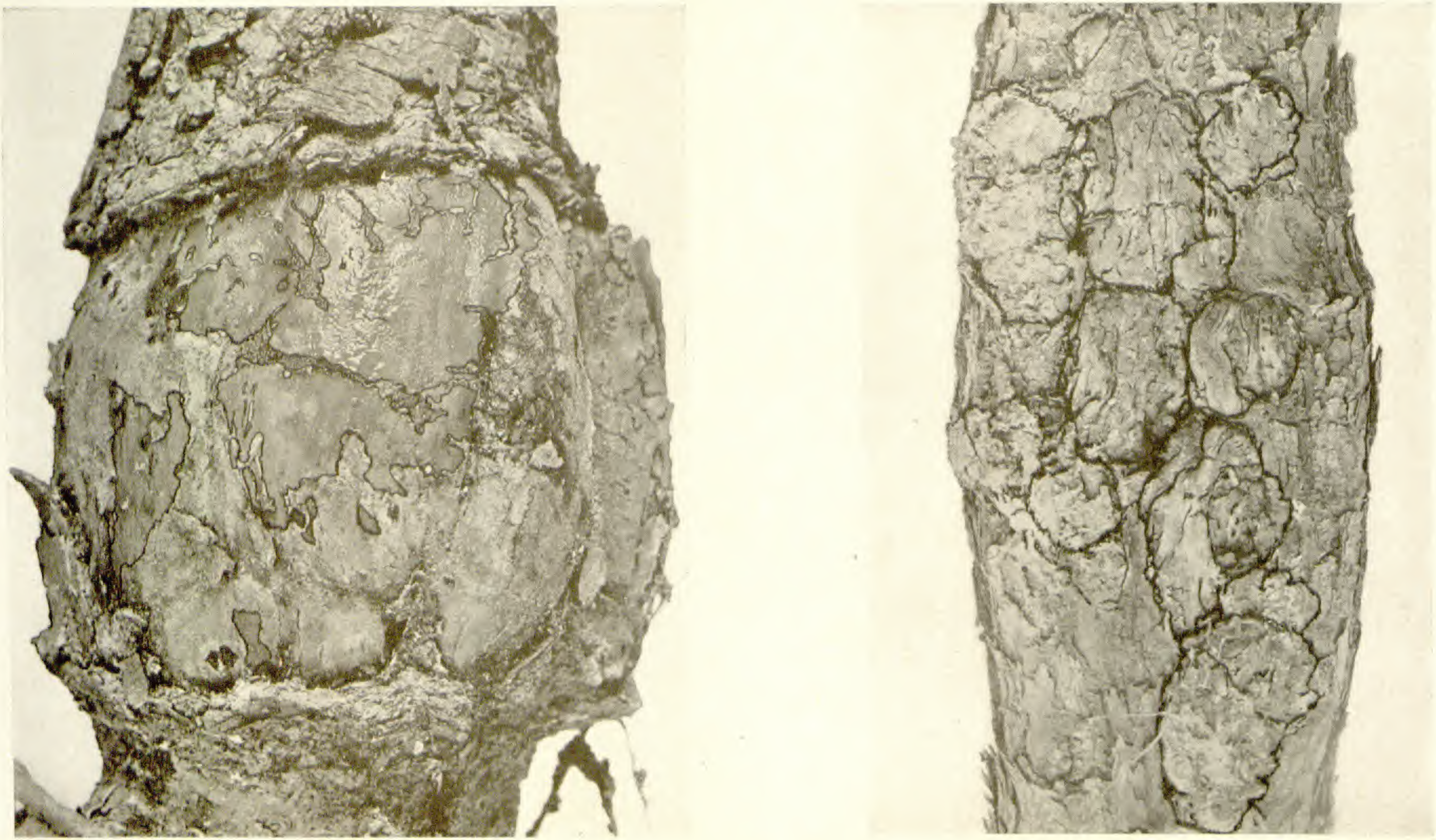
* Hedgcock, G. G., & Long, W. H. Identity of *Peridermium fusiforme* with *Peridermium Cerebrum*. Jour. Agr. Research **2**: 247–249. 1914.



PERIDERMIUM CEREBRUM Peck

PERIDERMIUM CEREBRUM PECK

PERIDERMIUM CEREBRUM PECK

as June 3. These seedlings were located within two feet of an infection at the base of a tree. The first collection of teleutosori was made on July 4 at Toms River. We have conducted infection experiments with this form of *P. Cerebrum* in the pine barrens of New Jersey and have obtained infections on these two species of oak and on *Q. heterophylla.*

EXPLANATION OF PLATES 4-6

PLATE 4

FIG. 1. *Peridermium Cerebrum* on *Pinus virginiana*, Bedford, Virginia, April 9, 1917. Portions of the thin cork layer have been removed at the center and above to show the extensive spermatial crust (portions outlined with ink). Natural size. About half of the surface shown has the spermatial layer exposed. The wavy outlines marking the boundaries of the exposed areas do not necessarily indicate the limits of the spermatia-bearing region. The very remarkable extent of the fertile layer is brought out strikingly. The small unpeeled patches at the center and above were at this time, at least, sterile regions, the significance of which is not very clear. Morphologically we should probably interpret the whole surface of the gall as one continuous spermogonial crust. The sterility of certain regions is doubtless accidental.

FIG. 2. From a photograph of a tree at Lakehurst, New Jersey, May 21, 1916. This shows how the fungus spreads by a series of migrations, giving rise to a number of associated galls. The original point of infection is shown by the oldest dead gall at the center. Three other dead galls are seen adjacent to it, above, at the right, and below. About the periphery of the canker are six or seven living galls. The galls were outlined with ink on the photograph. Tree 18 inches in diameter.

PLATE 5

FIG. 1. *Peridermium Cerebrum* on *Pinus rigida*, Toms River, New Jersey, 1916. The prevailing type of infection in this region causes a characteristic bending of the trunk. Infection beginning at the left has spread peripherally to the right. The galls at the left and center are dead. The one at the extreme right is living. Tree 10 inches in diameter at this point. (Cross-section of this specimen is shown in PLATE 6.)

FIG. 2. *Peridermium Cerebrum* on *Pinus rigida*, Toms River, New Jersey, June, 1916. Infection at base of tree about 12 inches in diameter. The infection spread peripherally. The dark area just at the right of the center is dead, but the bark still adheres. The other lobes of the gall are producing aecidiospores.

PLATE 6

Cross-section of the infected region of a trunk ten inches in diameter (a surface view of the same specimen is shown in PLATE 4, FIG. 1). Infection beginning at about third year, as shown by death of the wood in the right central part, has spread peripherally in both directions. The first gall has entirely disappeared owing to decay. On either side can be seen the remains of other galls that were formed with the first migrations of the fungus. At the left are two living galls.

THE VEGETATION OF THE HEMPSTEAD PLAINS

By Roland M. Harper

College Point, New York

WITH PLATE 7

Contents

Introduction

The Hempstead Plains, in the central part of Nassau County, Long Island, is a bit of prairie similar in aspect to parts of the Great Plains, and appearing quite out of place on the Atlantic seaboard. Its general geographical features were described by the writer a few years ago,* with a very superficial account of the

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* Bull. Am. Geog. Soc. **43**: 351–360. *f. 1–5.* May, 1911. Reprinted in abridged form, with a different set of illustrations, in Torreya **12**: 277–287. *f. 1–7.* Dec. 1912. These contain references to some earlier publications which do not need to be cited again here. See also New Internat. Encyc., ed. 2, **11**: 133. 1915.

vegetation. The present communication describes the vegetation more fully, but does not attempt a complete enumeration of the flora, which could very well constitute a separate paper of considerable length. Facts previously published will not be repeated here except where necessary for the continuity of the discussion, for the earlier papers are quite accessible.

Although this unique eastern prairie was mentioned in a few early histories and books of travel, and was well known to several local botanists a generation ago as a good place to collect certain species of plants, it was overlooked by all students of vegetation (as distinguished from flora)* until a very late date, when at least three fourths of it had already been obliterated. In a sketch of the fauna and flora of the neighborhood of Cold Spring Harbor by Dr. C. B. Davenport (the flora part contributed by Dr. D. S. Johnson), published in *Science* for Nov. 18, 1898, for the purpose of showing the attractions of that locality for botanists and zoölogists, there is no hint of the existence of a natural prairie, with its many interesting ecological problems, within five miles of the Biological Laboratory (and plainly visible to any one coming out there by train from New York). And for nearly ten years after that none of the botanists or ecologists who attended the summer school at Cold Spring Harbor as instructors or students seem to have known of this prairie, although some of them had lived or studied in Chicago and should have had some acquaintance with prairies.†

In Jelliffe's Flora of Long Island, 1899, there is no mention of

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* See Torreya 17: 1. 1917.

† There is much to be said in extenuation, however, and my own recognition of the unique character of this area was almost as tardy. I had read about the Hempstead Plains in the government soil survey report on western Long Island, by J. A. Bonsteel, in the spring of 1905, and visited Cold Spring Harbor once that year and twice the next, and walked a few times along the western and southern edges of the Plains as mapped in the soil survey report, without noticing anything unusual, until on July 3, 1907, I happened to cross the middle of the area on the way from the Merrick cedar swamp to Hicksville; and the facts were then irresistible. On my previous walks I had passed through only those parts where the original vegetation had been completely destroyed, and the portions visible from the railroad I had probably mistaken for abandoned fields, never having seen a real prairie before. Since 1913 I have obtained much valuable information about this area from Mr. Henry Hicks of Westbury, as did Dr. Bonsteel ten years before, and several subsequent explorers.

the Hempstead Plains, but Hicksville, which is in the heart of the area, is cited as a locality for about twenty species, collected by Dr. G. D. Hulst. (A few of these are introduced, but the majority are typical prairie plants.) The first specific mention of the Plains in botanical literature that has come to the writer's notice is a rather indefinite one in a short paper by William L. Fisher on Long Island violets in the *Plant World* (3: 91–92) for June, 1900. More explicit is a paper by James Kirby on "Some plants of Hempstead Plains" in the *American Botanist* (7: 110) for December, 1904 (published in May, 1905), which enumerates 14 species; about one third of which, however, do not properly belong to the prairie flora. In *Torreya* (6: 213) for October, 1906, a few species found in the same area by the Torrey Club excursionists on Sept. 1 are mentioned. In Dr. Harshberger's Phytogeographic Survey of North America (1911), page 421, is probably the most complete list of Hempstead Plains plants published up to that time, based on a walk of several miles through the area with the writer on Aug. 25, 1909.* By 1913 this prairie was sufficiently well known to plant sociologists to be featured as one of the attractions for the International Phytogeographic Excursion, most of the members of which visited it on July 27 of that year. Since then it has been on the regular field program of the summer classes in botany at Cold Spring Harbor. Taylor's Flora of the Vicinity of New York (1915) devotes nearly a page (29–30) to this area, and farther on, in the catalogue, eight species are recorded from the Hempstead Plains, besides a few weeds from Hempstead.

ENVIRONMENT

Area and topography. The area originally treeless was about fifty square miles, corresponding approximately with the Nassau County portions of the "Hempstead loam" and "Hempstead gravelly loam" as mapped in the government soil survey. (There seems to be no evidence that the areas of "Hempstead loam" in Kings and Suffolk counties were ever prairie.) By 1907 the area of natural vegetation had been reduced to about ten square miles, and probably at least a tenth of that has been destroyed since.

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* A more extended account appears on pages 170–171 of "The vegetation of the New Jersey pine-barrens," by the same author (1916).

Although the soil is not particularly fertile, the proximity of New York City makes truck farming more or less profitable under adverse soil conditions, and also causes large areas to be used for residential purposes irrespective of soil.

The topography is nearly flat, as in many other prairies, but the surface has a southward slope of about 15 feet per mile, which is rather steep for a prairie, though almost imperceptible to the eye. Several shallow valleys traverse the area in a general north and south direction, and a few of these are long and deep enough to have small permanent streams in them. The western slopes of the valleys are nearly always steeper than the eastern, possibly on account of the deflective effect of the earth's rotation,* though the amount of erosion since the glacial period must be very small.

Geology and soil. The whole area is underlaid by a mixture of coarse sand and siliceous pebbles, supposed to represent a glacial outwash deposit, the terminal moraine being just to the north. At any rate, it is very recent geologically. The groundwater level averages perhaps 30 feet below the general level of the uplands, which explains the dryness of most of the valleys and some of the peculiarities of the vegetation.

The soil proper is very characteristic, consisting of brownish silty loam covering the gravel to a depth of about a foot, except in the valleys, where it is thin or wanting. A mechanical analysis of a sample representing the uppermost 10 inches, from two miles northeast of Hicksville, is reported in the government soil survey as follows:†

	Per cent
Gravel (2–1 mm.)	2.70
Coarse sand (1–.5 mm.)	8.06
Medium sand (.5–.25 mm.)	3.96
Fine sand (.25–.1 mm.)	4.88
Very fine sand (.1–.05 mm.)	8.96
Silt (.05–.005 mm.)	49.20

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* See G. K. Gilbert, Am. Jour. Sci. 127: 431–432. 1884. Collier Cobb, Jour. Elisha Mitchell Sci. Soc., 10: 26–32. 1893. C. F. Brooks, School Sci. & Math. 17: 517–521. 1917.

† All particles exceeding 2 mm. in diameter are discarded in these mechanical analyses, which probably does not make much difference in this particular case, but would make a great difference in the corresponding subsoil. For this reason the subsoil analysis given at the same place is not worth copying.

Clay (.005–.00001 mm.)	22.20
Organic matter	8.26
Total	108.22

This has a higher percentage of organic matter than any other soil thus analyzed in the same report,* but this may mean merely that most of the other samples were taken from cultivated land, where the humus was long ago exhausted, for the virgin forests in the northwestern part of the island certainly have plenty of humus. Curiously enough, of all the mechanical analyses published for Long Island soils in the work mentioned, the one that matches this most closely is that of the "Galveston clay" (salt marsh) from two miles northeast of Far Rockaway. In fact the two analyses do not differ any more than two different ones of the same type of soil might be expected to. Whether or not this indicates that our prairie was once a salt marsh it is impossible to say; but, if it was, the surface must have undergone considerable tilting since, to give the Plains a southerly slope of one in 350; and it would not be very easy to explain why the prairie is separated from the present salt marshes by several miles of forest. It is possible also that some if not most of the soil has accumulated as dust in the course of centuries; but if that were the case it would be difficult to account for the absence of a dust layer in the surrounding forests, whose topography is very similar, and in many other level regions. Although the origin of the soil is not a botanical problem, this particular type of soil is so closely correlated with the prairie vegetation that one cannot help puzzling over it. No satisfactory explanation is available at the present writing, however.

A partial chemical analysis was reported in the first paper cited herein, and no additional information on that point has been obtained since. The amount of potash, one of the most important constituents, is entirely unknown. As elsewhere in the western half of Long Island, the soil fertility seems to increase a little toward the west, if the vegetation is a safe guide.

The small areas of bare ground between the tufts of herbage

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* Dr. Hilgard found only 1 per cent of humus in a sample carefully selected by the writer about a mile southeast of Hicksville.

are generally covered with minute lichens[*] and an occasional patch of moss, which presumably indicates that earthworms are rare or absent, for if they were at all common the earth brought up by them and deposited on the surface would tend to bury these very slow-growing plants. The lack of earthworms is probably due to the fact that the loam layer is shallower than the depth to which the ground freezes in winter, and the worms if present would hardly descend into the gravel to hibernate. There are a few ants, but their hills are not numerous enough to interfere seriously with the ground lichens.

On account of the porosity of the subsoil every heavy rain must carry down into the ground some of the soluble salts, thus making the soil progressively poorer. And this tendency cannot be counteracted to any considerable extent by capillarity, on account of the depth of the water-table, or by the soil fauna (as it seems to be in some other places[†]), for the ants, etc., probably do not go down into the gravel much.

Climate. The climate is cool-temperate, but with a long growing season on account of the proximity of Long Island Sound and the Atlantic Ocean, neither of which is more than ten miles away. There are no weather stations on or very near the Plains, but if we take the average of the data for New York City, Setauket, and Brookhaven we will probably be not far wrong. The New York records were taken from 1826 to 1864 at Jamaica, which is within ten miles of the west end of the Plains, and since then on Manhattan Island, at a gradually increasing altitude as the buildings became taller. The Brookhaven records cover the period from 1864 to 1882, and those for Setauket from 1886 to 1909. The data given are the average temperature, in degrees Fahrenheit, and precipitation, in inches, for each month and for the whole year.

Months	Temperature	Precipitation
January	30.4	3.70
February	30.0	3.81
March	37.3	4.31
April	47.9	3.59

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[*] Mostly *Cladonia symphycarpa epiphylla*, according to Mr. R. S. Williams, who identified a specimen for me recently. The moss is mostly *Polytrichum juniperinum*.

[†] See Ann. Rep. Fla. Geol. Surv. **7**: 147. 1915.

May	58.7	3.69
June	67.8	3.02
July	73.3	4.04
August	71.7	4.14
September	65.5	3.47
October	54.8	3.84
November	44.1	3.85
December	34.5	3.83
Annual	51.3	45.28

The average growing season, or period free from killing frost, is from April 10 to November 7, 211 days. In this respect our area compares favorably with some places five hundred miles farther south, say in Georgia and Alabama. June is the driest month by a small margin, but it would be hard to find a place with a more evenly distributed precipitation. There are no accurate data on wind, sunshine, evaporation, humidity, or snowfall; but the average annual amount of the last is probably something like two or three feet.

Vegetation

Habitats. The natural vegetation may be divided into two habitat groups: that of uplands and that along watercourses. In a more detailed study the gravelly slopes of the valleys with the beds of the dry ones might make a third group, but the vegetation of such places, though differing a little in composition, is so similar in aspect to that of the level uplands that it is hardly worth while to separate it. There is also a characteristic weed vegetation along roads and in abandoned fields, which will be discussed briefly farther on. The upland vegetation is by far the most extensive, but that of the valleys is (or was) a little richer in species. The next few pages will deal with the natural upland vegetation exclusively, unless otherwise indicated.

Aspects. The prevailing aspect of the vegetation is a moderately dense growth of coarse grasses and other herbs, averaging about two feet tall, with a sprinkling of shrubs of about the same height, and a few trees, either solitary or in small open groves. All the woody plants are most abundant eastward, except the commonest shrub, which is pretty uniformly distributed. There are no stout broad-leaved herbs like the Silphiums of the Middle Western prairies, but on the other hand there are few evergreens or succulents. The prevailing color of the herbage in summer is grayish green, on account of the prevalence of glaucous and canescent leaves,* but the scene is brightened by flowers of various colors, changing from month to month as in many other grass-lands and the southeastern pine-barrens. In the fall, the color gradually changes to light brown, with a strong shading of gray from the plumose spikelets of the prevailing grass (which grows on nearly every square foot of upland, and makes up something like three fourths of the total herbaceous vegetation).

FIG. 1. Typical prairie scene about 1¼ miles northeast of Hicksville, looking south. *Andropogon* and *Baptisia* in foreground, farm-house and a few shade-trees in middle distance, and edge of forest barely visible on the horizon. 2:05 p.m., Oct. 20, 1907.

On account of the small size of this prairie one could stand at any point on the upland and see the surrounding forests in every direction if buildings and shade-trees did not interfere; but in the western part one can step down into one of the shallow valleys and get an absolutely treeless horizon in some directions, indistinguishable in a photograph from some places far out on the Great Plains.†

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* In this connection see Wiegand, Bot. Gaz. **49**: 430–444. 1910.

† See PLATE 7, and compare this with a scene in western Kansas published in Bull. Am. Geog. Soc. **40**: 338. June, 1908.

Fire. Fire seems to be a normal environmental factor in this prairie, as in all others more than a few acres in extent,* but just what its normal frequency may have been in prehistoric times it is impossible now to determine. Nearly all the herbs and shrubs have thick or matted subterranean rootstocks, so that they sprout up again readily after a fire. Plants with barbed fruits (which are most effective in dissemination if they remain on the plant for several months) seem to be entirely absent, and shrubs with nuts or berries generally grow in clumps, whose centers are thus protected from fires of moderate intensity. Woody vines (all of which seem to be sensitive to fire) are scarce, and chiefly confined to the clumps of bushes in the eastern part and to the valleys. The commonest tree on the Plains, the gray birch, is often partly protected by a cluster of shoots around its base, and it is rather short-lived anyway, so that young trees spring up as

FIG. 2. Edge of oak grove near the railroad, about two miles north of Hicksville, looking S.S.E., showing *Quercus Marylandica, Q. stellata,* and the herbaceous vegetation characteristic of dry prairies. 12:20 p.m., Oct. 20, 1907. The trees evidently have, and need, little or no protection from fire running through the grass. (The view in Torreya **12**: 282 was taken from the same point.)

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* See Plant World **20**: 60. "Feb." 1917.

fast as the older ones are killed by fire. The pines and oaks scattered over the eastern part of the Plains are of species not very sensitive to fire, so that they do not need to grow in dense groves for protection, like the prairie groves of the Mississippi valley.* The original boundary between prairie and forest here has been almost entirely obliterated by cultivation, but it was probably rather sharp in most places, for the regular forest trees of Nassau County, both north and south of the Plains, are mostly of species not very tolerant of fire, and the fires probably stopped abruptly at the edge of the forest, where the shade kept the humus too damp to burn readily.

FIG. 3. Portion of pine grove ("Island of Trees") in prairie about a mile southwest of Central Park, showing especially *Pinus rigida* and *Baptisia tinctoria*. 2:47 p.m., Aug. 25, 1909. In the absence of shrubby undergrowth this place differs notably from the pine-barrens of Long Island and New Jersey, and resembles some of those in the southeastern states. (For another view of the same grove see Bull. Am. Geog. Soc. **43**: 359.)

It seems rather strange for the ground to be covered with lichens and sprinkled with mosses in an area subject to ground fires, for these plants are supposed to be very sensitive to fire; but probably any one spot on the uplands does not get burned over more than once in two years, on the average. And the commonest lichen is so minute and close to the ground that fire

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* See Gleason, Bot. Gaz. **53**: 38–49. 1912; Torreya **13**: 173–181. 1913.

jumping from one tuft of grass to another may pass over it without doing much injury, and the mosses and fruticose lichens are mostly in gravelly places, where the vegetation is too sparse to make much of a blaze.

The vegetation of the wet valleys seems to be practically exempt from fire.

Plant census. The approximate relative abundance of the species has been ascertained by a rapid reconnoissance method which is a crude modification of Clements's quadrant method. I have traversed the area on foot repeatedly in every direction (mostly in the summers and falls of 1907 to 1909, with a few additional observations made in passing through in 1916 and 1917), and in so doing have stopped every few yards or rods and jotted down the name of every plant in sight, indicating relative abundance by a somewhat arbitrary scale. When hundreds of such little lists are combined they ought to give the relative abundance (combined with size and duration) of the species pretty accurately, for the largest and most abundant species of course are noted oftenest. Herbs which are recognizable only during a brief period when they bloom naturally do not figure as largely in the returns as the more lasting ones, but that is all right, for the ephemeral species do not take as much water, etc., from the soil and make as much hay as the others.

On account of the difficulty of making proper allowance for plants of different sizes, ranging all the way from lichens to trees, and the great preponderance of one species among the herbs, I have not ventured to assign percentages to the several species. But when the percentages are finally worked out and arranged in numerical order they will probably make something like a geometrical progression, for in all areas of natural vegetation that are large and homogeneous enough there seem to be many more small and rare species than large and abundant ones; just as in human society there are always more insignificant people than celebrities, more poor men than millionaires, or more small towns than large cities.

In the following lists trees, shrubs, herbs, and cellular cryptogams are separated, and arranged in order of abundance in each group, as usual. A few of those seen least often are omitted, on account of the considerable possibility that they may have been introduced, or wrongly identified. The names of evergreens are in heavier type, and those of a few species of weedy tendencies, which may not have been in the prairie in prehistoric times, are put in parentheses.

The nomenclature is in most cases identical with that in Taylor's Flora of the vicinity of New York (1915); and where it differs from that it conforms with other easily accessible works. After the name of each species is put the numbers of the months in which it normally blooms, the prevailing color of its flowers (replaced by a dash in the case of wind-pollinated species which have no organs for attracting insects), and a symbol indicating the mode of dissemination, when known. Wind-disseminated species (including tumble-weeds) are indicated by Y, tonoboles* (i. e., plants with capsules or firm cup-like calyces borne on stiff stems which stand up through the winter) by T, berries and nuts by O, and pods which discharge their seeds by elastic force by E. One could go still farther and have symbols or abbreviations for annuals and perennials, the Raunkiaerian growth-forms, various types of leaf, etc.,† but it is just as well not to undertake too much at one time, and some of these matters—as well as the authors' names, common names, phaenological curves, etc.—can very well be deferred to a more exhaustive study of the flora.

The first list is for uplands and dry valleys.

TREES

Betula populifolia	5	——	Y
Quercus marylandica	5	——	O
Quercus stellata	5	——	O
Pinus rigida	5	——	Y

SHRUBS

Pieris Mariana	5–7	white	T
Salix tristis (?)‡	4	——	Y
Quercus prinoides	5	——	O
(*Populus tremuloides*)§	4	——	Y

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* See Clements, Bot. Surv. Neb. **7**: 47. 1904.

† See Ann. N. Y. Acad. Sci. **17**: 36–38 (1906) for a more elaborate method of treating plant association lists.

‡ This could just about as well be *S. humilis*. No one seems to have succeeded in drawing a sharp line between the two forms.

§ This is normally a small tree, but on the Hempstead Plains it seldom gets more than three or four feet tall, perhaps on account of the frequent fires.

Gaylussacia baccata	5	pink	O
Comptonia peregrina	5	——	
Rhus copallina	7–8	yellow	O
Myrica carolinensis	5	——	O
Quercus ilicifolia	5	——	O
Corylus americana	4	——	O
(*Rubus cuneifolius*)	5–7	white	O

HERBS

Andropogon scoparius	8–9	——	Y
Ionactis linariifolius	9–10	blue	Y
Baptisia tinctoria	6–9	yellow	Y
Aster dumosus strictior	9–10	white	Y
Crocanthemum sp.*	5–8	yellow	
Cracca virginiana	6	cream and purple	E
Aletris farinosa	6–7	white	T
Viola pedata	5	blue	E
Solidago puberula(?)†	9–11	yellow	Y
Antennaria neglecta	4–5	white	Y
Agalinis acuta‡	9	pink-purple	T
Lespedeza capitata sericea	8–9	cream	5
Juncus Greenei	6	green	T
Lechea villosa	7–8	dark purple	T
(*Euthamia tenuifolia*)	9–10	yellow	Y
Scleria pauciflora	6–7	——	
Sorghastrum nutans	9	——	
Sisyrinchium sp.	5–6	blue	
Linum intercursum§	7–8	yellow	T
Polygala Nuttallii	7–9	pink	
Hypoxis hirsuta	5–6	yellow	
Lechea maritima	7–8	dark purple	T
(*Potentilla canadensis*)	5	yellow	
Sericocarpus linifolius	7–8	white	Y
(*Agrostis alba?*)	5–6	——	Y
Polygala viridescens	8–9	pink	
Carex pennsylvanica	4–5	——	
Lespedeza angustifolia	8–9	cream	T
Eupatorium hyssopifolium	8–10	white	Y
Viola fimbriatula	4–5	blue	E
Cirsium discolor(?)	6–7	pink-purple	Y
Polygala polygama	6–8	pink-purple	
Andropogon furcatus	9	——	Y

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* There may be more than one *Crocanthemum* (long known as *Helianthemum*). in which case both would take a lower rank in the list. See Bicknell, Bull. Torrey Club **40**: 613–615. 1913. Fernald. Rhodora **19**: 58–60. 1917.

† Some *S. nemoralis* may have been included with this.

‡ Described since Taylor's Flora, in Bull. Torrey Club **42**: 338–340. June, 1915. Formerly referred to *Gerardia decemloba*, a species of more southerly range.

§ Bicknell, Bull. Torrey Club **39**: 418. 1912. Previously confused with *L. medium* or *L. floridanum*. See also C. A. Weatherby, Rhodora **18**: 224. 1916.

Bartonia virginica	8–9 cream
Viola lanceolata	5 blue E
Houstonia longifolia	5–6 pink-purple T
(*Sarothra gentianoides*)	8–9 yellow
Antennaria plantaginifolia	4–5 white Y
Comandra umbellata	5–6 white
Ibidium gracile	8–9 white

CRYPTOGAMS

Cladonia symphycarpa epiphylla (and others)
Polytrichum juniperinum
Boletus sp.

As in many other parts of the country, the trees all have vernal wind-pollinated flowers, and the same is true of most of the shrubs. Among the herbs the commonest species is wind-pollinated, but most of the others have yellow, white, or blue flowers (with little or no odor). There are more herbaceous flowers in spring than in midsummer, and more in fall than in spring, at least if we consider species regardless of their relative abundance. Plumose seeds or fruits prevail among the herbs, but "tonoboles" are quite common also. None of the herbs seem to have fleshy fruits, but the nut-like fruits of *Comandra* may be eaten by small mammals. Some of the smaller herbs, particularly the Polygalas, have appendaged seeds which are thought to be adapted to transportation by ants.

Some dynamic studies of the upland vegetation were made in 1916. On Oct. 27, about a mile S.S.E. of Westbury Station, a typical sample of herbaceous vegetation, consisting chiefly of *Andropogon scoparius* (which constitutes the bulk of the herbage of the Plains) was cut close to the ground from a small measured area, so as to get the total annual growth per unit area, exclusive of a small amount of stubble and roots. It weighed 8,220 pounds per acre at the time, but then growth had probably ceased and the drying out begun, so that if it had been cut a month earlier the weight might have been greater. The same vegetation when air-dry weighed 5,975 pounds per acre, which is probably less than the average annual increment of vegetation in the eastern United States, though much higher than figures obtained by Shantz for somewhat similar vegetation in eastern Colorado.*

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* U. S. Bur. Plant Industry Bull. 201: 81. 1911.

The ash weighed 265 pounds per acre, or between 4 and 5 per cent of the air-dry weight.

According to some of the old inhabitants, the Plains vegetation formerly grew taller than it does now. This probably does not mean that the *Andropogon scoparius* was any taller, but that the taller grasses, such as *A. furcatus* and *Sorghastrum* (which are said to be more characteristic of the fertile prairies of the West), were more abundant. If that is true the annual growth per unit area must be decreasing, which is consistent with the suggestion on a preceding page about the progressive impoverishment of the soil. And the fact that the groves of pines at Island of Trees are composed of rather small trees appears to indicate a comparatively recent invasion, which would be in harmony with the same tendency, for *Pinus rigida*, like most other pines, flourishes in very poor soils. But one would hardly suppose that the soil could deteriorate so rapidly that the difference in vegetation would be noticeable in a lifetime, and there may be some entirely different explanation for the supposed change in vegetation.

The vegetation characteristic of the wet valleys is very limited in extent. The largest stream on the Plains is East Meadow Brook, which rises about three miles east of Garden City and flows south about a mile before passing into the forest region. Most of its vegetation within the prairie area has been destroyed in the last few years, unfortunately, and the brook itself is nearly dry now, but pretty full notes were taken there in 1907–1909. Hempstead Brook, which flows through the eastern part of the village of Hempstead, is next in importance, and there is a smaller brook about two miles farther west which still has a trace of its original vegetation.

Along the streams there are no trees except a few small specimens of *Acer rubrum* and *Nyssa*, scarcely rising above the shrubbery, but the shrubs are considerably larger than those of the uplands, many of them being higher than a man's head. Fire seems to be a negligible factor in the environment.

The meadow plants are divided into small trees and shrubs, vines and undershrubs, herbs and mosses. Otherwise the treatment is the same as that of the upland vegetation, the rarer species being omitted, for the reasons already given.

SMALL TREES AND SHRUBS

Rhus Vernix	6–7	cream	O
Myrica carolinensis	5	——	O
Viburnum dentatum	5–6	white	O
Rosa palustris	6	pink-purple	
Cholisma ligustrina	6–7	white	
Spiraea latifolia	6–7	white	
Aronia nigra	5	white	O
Spiraea tomentosa	7	pink-purple	
Pieris Mariana	5–7	white	
Sambucus canadensis	6–7	white	O
Vaccinium corymbosum?	5	white	O
Acer rubrum	4	red	Y

VINES AND UNDERSHRUBS

Rubus hispidus	6–7	white	O
Rhus radicans	5–6	cream	O
Oxycoccus macrocarpus	6–8	pink	O

HERBS

Dulichium arundinaceum	6–8	——	
Lycopus sp.	8–9	white	T
Hypericum adpressum	7	yellow	T
Vernonia noveboracensis	7–9	purple	Y
Osmunda cinnamomea			
Eupatorium perfoliatum	8–9	white	Y
Panicum virgatum	7–8	——	
Juncus canadensis?	7–8	green	T
Dryopteris Thelypteris			
Lysimachia terrestris	6–8	yellow	
Kneiffia linearis?	6–8	yellow*	
Eriophorum gracile?	5	——	Y
Rhynchospora alba	7–8	white	
Polygala cruciata	7–9	pink	
Eriocaulon septangulare	7–9	white	
Rhexia virginica	7–9	pink-purple	T
Polygonum sagittatum	6–10	white	
Triadenum virginicum	7–9	pink-purple	T
Gentiana Saponaria	9–11	blue	T
Sparganium sp.	7–8	——	
Linum striatum	7–8	yellow	
Viola primulifolia	5	white	E
Juncus acuminatus?	6–8	green	T
Helianthus angustifolius	8–9	yellow	
Onoclea sensibilis			
Osmunda regalis			

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* See Plant World **8**: 301–303. 1906. In that paper the false common name "evening primrose," which belongs to the related genus *Oenothera* but decidedly not to *Kneiffia*, was inserted by the editors without the writer's knowledge or consent. The figures are four times natural size.

Agalinis purpurea	8–10	pink-purple	T
Viola lanceolata	5	white	E
Gratiola aurea	6–7	yellow	
Xyris sp.	7–9	yellow	T
Ludwigia alternifolia	6–8	yellow	T
Carex sterilis?	5	——	
Eriophorum virginicum	7	——	Y
Eupatorium purpureum	6–8	pink-purple	Y
Castalia odorata	6–9	white	
Asclepias pulchra	7–8	pink-purple	Y
Rhynchospora glomerata	6–8	——	
Euthamia tenuifolia	8–10	yellow	Y
Drosera intermedia	6–8	pink-purple	
Potamogeton sp.	7	——	
Hypericum canadense	7–9	yellow	T
Carex lurida	5	——	
Solidago rugosa	8–10	yellow	Y
Sagittaria latifolia	8–9	white	
Eleocharis melanocarpa	6–7	——	
Aster salicifolius?	9	blue	Y
Lycopodium adpressum			
Lobelia Nuttallii	7–9	blue	
Ibidium cernuum	9–10	white	Y
Aletris farinosa	6–7	white	T
Juncus Greenei	6	green	T

MOSSES

Sphagnum sp. (perhaps more than one)

The majority of the shrubs and vines bloom in early summer and have white flowers and fleshy fruits. Among the herbs the proportion of aestival pink-purple flowers, and of tonoboles, is noticeably larger than on the uplands, and there are few or no fleshy fruits. There are, however, many species whose mode of dissemination is not certainly known.* Some of these doubtless have seeds that float downstream, and are carried in other directions on the feet of aquatic birds. The shrubs that bear capsules are perhaps to be classed as tonoboles.

Weeds. Many of the roads across the Plains are entirely unimproved, mere wheel-tracks, which are shifted a little from time to time as the ruts become too deep, in precisely the same manner as some of those in eastern Colorado described recently by Shantz.† Along almost every such road can be found *Euthamia*

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* See Torreya **8**: 159. 1908.

† Jour. Ecology **5**: 19–42. *f. 1–23.* March, 1917. Several of the illustrations in that paper could be matched very closely on the Hempstead Plains, and much of the text would apply very well too, except for the names of the plants discussed.

tenuifolia, which may be native in some parts of the eastern United States, but nearly always grows in places whose naturalness is not above suspicion, all the way from here to Florida. *Agrostis alba* is very common also along roads, and most of the other species whose names are in parentheses in the upland vegetation list grow in similar places, where the original vegetation has been damaged without much disturbance of the soil. None of them seem to invade undisturbed vegetation, however.

Where the soil has once been plowed up and cultivated many additional weeds, such as *Oenothera biennis*, *Ambrosia artemisiifolia*, *Persicaria* sp., *Linaria vulgaris*, *Daucus Carota*, *Syntherisma sanguinalis*, and *Aster ericoides*, come in, and these seem able to hold the ground indefinitely against a re-invasion by native species. Very little attention has been paid to this particular phenomenon as yet, but there will be time enough for it after the natural vegetation, which needs more immediate attention, is all gone.

COMPARISONS WITH OTHER REGIONS

There is no precisely similar vegetation anywhere else, as far as known, but there are many places near and remote with vegetation somewhat similar in aspect or composition, or both. Among the nearer places are the so-called heaths of Nantucket, described by Harshberger,* and Block Island, Montauk Point, and various other places near the coast of southern New England, if we may judge by the few photographs and fragmentary floristic descriptions that have been published, though in some of these cases the treelessness is said to be the result of deforestation within historic times.

The "hilltop barren formation" of eastern Massachusetts, described by Blankinship,† has quite a number of species in common with the area under consideration. In the government soil survey of Rhode Island by F. E. Bonsteel and E. P. Carr, published in 1905, there is described a "Miami silt loam,"‡ occurring principally in the township of South Kingstown, in the

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* Bull. Geog. Soc. Phila. 12: 73–76. 1914.

† Rhodora 5: 128. May, 1903.

‡ In a subsequent publication of the Bureau of Soils this was changed to "Merrimac silt loam," a type of soil not reported outside of Rhode Island, and classed as a glacial lake deposit.

southern part of the state, which must be very similar to the "Hempstead loam," the principal differences brought out in the description being that the sand and gravel begin about three feet below the surface instead of one, and the ground-water level is much nearer the surface, sometimes rising above it in rainy weather or when snow is melting rapidly. The soil survey report says little or nothing about the vegetation, but in *Rhodora* (**9**: 117–122) for July, 1907, there is a paper on The flora of the Great Swamp of Rhode Island, by E. S. Reynolds, which throws some light on the subject. The Great Swamp, which borders Worden's Pond, is immediately south of the "Miami silt loam" areas, and Reynolds's list includes quite a number of species which are certainly not swamp plants, and may have come from the silt loam area, though habitats and localities (and abundance) are not indicated. Species previously collected by others in the same neighborhood are excluded from his list, and the reader is given no intimation of what those might be, except that they are about as numerous as those listed. Under the circumstances, therefore, it is interesting to find in Reynolds's list the following which are characteristic of the upland vegetation of the Hempstead Plains (taking them in the same order in which they appear in the present paper): *Rhus copallina, Baptisia tinctoria, Viola pedata, Solidago puberula, Lespedeza capitata, Hypoxis, Bartonia virginica, Ibidium* (*Spiranthes*) *gracile.* And it is reasonably certain that among the species collected by others and therefore ignored by Reynolds there are other typical Hempstead Plains plants*. The similarity of his list to our meadow vegetation is of course much closer, as he was ostensibly dealing with swamp plants only.

The sand-plains of North Haven, Connecticut, described by W. E. Britton,† also have many of the same species as our area, and Dr. G. E. Nichols has sent me photographs of parts of those sand-plains where the herbage was denser than any figured by Dr. Britton, and appeared much like that of the Hempstead Plains. The sand barrens of southern Staten Island, according to S. H. Burnham,‡ are likewise characterized by some of the same species.

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*For example, Fernald, in Rhodora **19**: 58, reports *Crocanthemum dumosum* from South Kingstown.

† Bull. Torrey Club **30**: 571–620. *pl. 23–28.* 1903.

‡ Torreya **13**: 249–255. Nov. 1913.

Other marked similarities to our area, floristic or vegetational, are found in the serpentine barrens of Pennsylvania and Maryland, discussed by Harshberger,* Pennell,† and Shreve,‡ and the sand areas of Illinois, described by Gleason and others.§ (The typical Illinois prairies, however, have much richer soil and more luxuriant vegetation, with more broad-leaved herbs and almost no shrubs.)

Still farther west we can find a number of resemblances in the sand-hills of western Nebraska, described by Rydberg‖ and Pool.¶ The less typical sand-hills of northeastern Colorado, visited by the writer under the guidance of Dr. Shantz in August, 1915, are probably more like the Hempstead Plains than are those of Nebraska, for the vegetative covering is more continuous. The dominant grass on the Colorado sand-hills is the same as on the Hempstead Plains (or at least taxonomists have not yet separated them). The regular short-grass prairie in the same neighborhood also has some features in common with that under discussion. Instead of our *Baptisia tinctoria* there is another leguminous plant of much the same aspect, namely, *Psoralea tenuiflora*.** The similarity of roadside conditions there and on Long Island has already been mentioned under the head of weeds.

The gravelly prairies south of Puget Sound, described by Piper,†† resemble ours in being level and grassy, with scattered oaks, and even have a species of *Sericocarpus*, the only member of the genus that grows outside of the eastern United States.

Considering briefly the southeastern states, the dry fields of Middle Georgia have several of the same plants as the Hempstead Plains uplands, and the prairie meadow plants are pretty well

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* Science II. **18**: 339–343. Sept. 11, 1903.

† Proc. Acad. Nat. Sci. Phila. **62**: 541–584. 1911; **64**: 520–539. 1913.

‡ Plant Life of Md. 213–215. *pl. 20.* 1910. The writer had opportunity to visit some of the well-known serpentine barrens near Baltimore and Philadelphia in June, 1917. An early description, primarily mineralogical, of those nearest Baltimore is by Dr. H. H. Hayden in Am. Jour. Sci. **24**: 349–360. 1833.

§ Bull. Ill. State Lab. Nat. Hist. **7**: 149–194. Jan. 1907; **9**: 23–174. *pl. 1–20.* 1910.

‖ Contr. U. S. Nat. Herb. **3**: 133–200. *pl. 1, 2.* 1895.

¶ Minn. Bot. Stud. **4**: 189–312. *pl. 26–40.* 1914. Reviewed in Bull. Am. Geog. Soc. **47**: 873–874. Nov. 1915.

** For descriptions of prairie vegetation in Colorado, see Shantz, U. S. Bur. Pl. Ind. Bull. 201, 1911; particularly, *plate 3. fig. 1.* and *plate 4. fig. 1.*

†† Contr. U. S. Nat. Herb. **11**: 42–44. *pl. 9, 10.* 1906.

represented in the meadows of the same neighborhood, and also in western North Carolina, though these southern grass-lands may have once been wooded.*

Lastly, by way of contrast, we may consider the pine-barrens of Long Island, which begin immediately east of the Plains. The flora of the two regions has much in common, but the vegetation is very different.† There are also some differences between representatives of the same species in the two areas, which may possibly hereafter be made the basis of subspecific distinctions. For example, *Quercus prinoides* on the prairie has nearly simple stems in large clumps, with broader, thinner, and paler leaves than in the pine-barrens; and *Sericocarpus linifolius* has broader and more numerous leaves on the prairie, presumably indicating better soil, notwithstanding the greater exposure to sun and wind, which ought to have just the opposite effect on leaves, if other factors were equal. Of the two shrubby oaks characteristic of both places, *Quercus ilicifolia* outnumbers *Q. prinoides* at least ten to one in the pine-barrens, while on the Plains the latter is at least twice as abundant as the former.

A discussion of the geographical affinities of the flora, the families and genera most numerously represented or conspicuous by their absence, etc., belongs more properly to a floristic paper. But it may be noted in passing that most of the upland species are widely distributed in sunny places, on rather poor soils, in the northeastern United States south of the boreal conifer region, and almost none of them are found in Europe or near the Pacific coast. Few if any are confined to the coastal plain. The two arborescent oaks, one of which reaches its northeastern limit here, while the other extends to Massachusetts, have been seen by the writer, or are reported by others to occur, usually together, on the coast of New Jersey, on the edges of the serpentine barrens of Pennsylvania and Maryland and dry prairies in Illinois, Missouri, and Arkansas, around flat rock outcrops in Georgia and Alabama, in the prairies, flatwoods, and barrens of Alabama and Mississippi, and lastly in the "cross-timbers" of Oklahoma and Texas, where they are said to constitute the bulk of the forest. Both reach

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* See Bull. Torrey Club **27**: 322, 327. 1900; Torreya **10**: 63. 1910.

† See Torreya **8**: 1–9. 1908.

their southern limits in the northern edge of Florida, as do some of the other plants under consideration.

Among the most widely distributed members of the upland vegetation, besides the two oaks just mentioned, are *Rhus copallina*, *Andropogon scoparius*, *Cracca virginiana*, *Aletris farinosa*, *Viola pedata*, *Sorghastrum nutans*, *Hypoxis hirsuta*, *Carex pennsylvanica*, *Polygala polygama*, *Andropogon furcatus*, and *Antennaria plantaginifolia;* while some of the most local are *Aster dumosus strictior*, *Crocanthemum dumosum*, *Agalinis acuta*, *Juncus Greenei*, and *Linum intercursum*. (These last are all reported also from Nantucket Island.) The species which are probably more abundant here than in any other equal area in the world, in addition to the five last named, are *Pieris Mariana*, *Quercus prinoides*, *Andropogon scoparius*, *Ionactis*, *Baptisia tinctoria*, *Viola pedata*, *Antennaria neglecta*, *Lespedeza capitata sericea*, *Scleria pauciflora*, *Sericocarpus linifolius*, *Lespedeza angustifolia*, and *Eupatorium hyssopifolium*.*

The meadow plants are more widely distributed, on the whole, than those of the uplands, most of them ranging from Canada to Georgia at least.

DESTRUCTIVE INFLUENCES

Finally the influences tending to destroy the prairie vegetation may be reviewed briefly. When the neighborhood was first settled, in the seventeenth century, it was soon discovered that the Hempstead Plains was not very well adapted to agriculture, and for a century or two the greater part of it was treated as public property or free pasture, much as unfenced land in the more thinly settled states is today. Grazing has continued in a small way down to the present time, but the area has probably never been overgrazed sufficiently to weaken the native vegetation and allow weeds to enter, except in enclosures near dwellings.

The absence of trees and rocks and hills made cultivation very easy, however, so that some farms were established on the Plains at an early date in spite of the povery of the soil (which could be counteracted to some extent with manure, etc.), to supply

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* Future species-splitting may require modification of some of the statements in this paragraph, but apart from that they can hardly be challenged until the vegetation of a number of other areas is studied quantitatively.

the surrounding villages, before easy railroad communication with the interior of the country made it more economical to bring part of the food supply from the more fertile lands of the West. Agriculture on the Plains, as elsewhere on Long Island, probably reached its maximum extension two or three generations ago. Census statistics for Nassau County go back only to 1900, for it was not separated from Queens until 1899, but the number of farms in the county decreased from 1,658 in 1900 to 1,017 in 1910, and the acreage of farm land decreased during the same period from a little over half the total area to less than a third, and is doubtless still less now.* But prairie land once cultivated and afterwards abandoned seems never to revert to the original vegetation, as pointed out under the head of weeds; or at least if it does the process is so slow that no evidences of it have yet been discovered.

At the present time more of the land is used for residential purposes than for agriculture, the proximity of New York City and the ease of communication causing many people to settle on and around the Plains quite independently of soil conditions. Nassau County had 202 inhabitants per square mile in 1900 and 303 in 1910, and probably has about 400 now. Although this causes considerable encroachment on the prairie and may be the ultimate means of obliterating it, in a way it tends to protect it from agricultural exploitation, for it makes some of the land too valuable for farmers to touch, just as there is said to be more natural prairie now inside the city of Chicago than for a considerable distance outside, for a similar reason.

A more serious menace at the present time is the appropriation of considerable areas for pleasure purposes, such as polo and golf; the latter having brought about the destruction of most of the Meadow Brook vegetation a few years ago, causing keen regret to nature-lovers. For there are innumerable suitable sites for golf

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* There was less than half as much farm land and only a little more than half as much cultivated land, on Long Island in 1910 as in 1850, when such statistics were first included in the census. The farmers are evidently being crowded out by commuters and millionaires. In the last few years the Garden City Company, perhaps unmindful of the rapid decline of farming on Long Island and the futility of trying to counteract it, has plowed up several hundred acres of virgin prairie by machinery and offered to lease the land to farmers (see news item at bottom of page 113 of Torreya for June, 1914), but apparently without much success.

links, but only one Meadow Brook. (The name East Meadow Brook does not necessarily imply that there were two, but was probably applied originally simply to designate the brook flowing through the East Meadow: i. e., east of Hempstead.)

During the Spanish-American war in 1898 some of our soldiers were encamped on the Plains near Mineola (Camp Black), and in 1917 a much larger encampment (Camp Mills) was located east of Garden City and Hempstead, causing the trampling down or otherwise injuring of about a square mile of vegetation, which will probably never fully recover.*

When the aëroplane became an accomplished fact, in 1909, the Hempstead Plains was very soon selected as an ideal place to experiment with the new means of locomotion, on account of the large flat area comparatively free from obstructions, and its proximity to our largest city. The necessary buildings and regular alighting places have encroached on the prairie a little near Mineola, but otherwise this industry has done little damage; and it probably deserves the good wishes of botanists, for it is decidedly to the interest of the aviators that no more of the Plains should be cultivated or built upon. There was indeed once a little complaint from them that the surface was a little too rough (from the tufts of grass, no doubt), and should be smoothed, but they have apparently become reconciled to that.

Let us hope that the State or the federal government or some public-spirited organization will soon take steps to preserve the rest of this unique and easily accessible prairie permanently from further encroachments, for the benefit of aviators, even if the interests of plant sociologists and other nature-lovers are not considered at all in these days of commercialism. But if it comes to the worst the southeastern corner of the Plains, which is remotest from settlements, will probably have some of its natural vegetation still in condition for study two or three generations hence, and some important ecological principles may yet be discovered there.

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* A news item sent from Camp Mills to the daily papers on Oct. 21, 1917, mentioned the menacing of the camp by a prairie fire; something that some of the western soldiers may have been familiar with, but could hardly have expected to see so near the metropolis.

At least four other chapters should be written about this unique area by competent persons before it is too late: one on its geology, with special reference to the origin of the soil; one on its flora, with attention to the points mentioned on pages 273 and 282, and others easily called to mind; one on its fauna; and one on its agricultural and economic history.

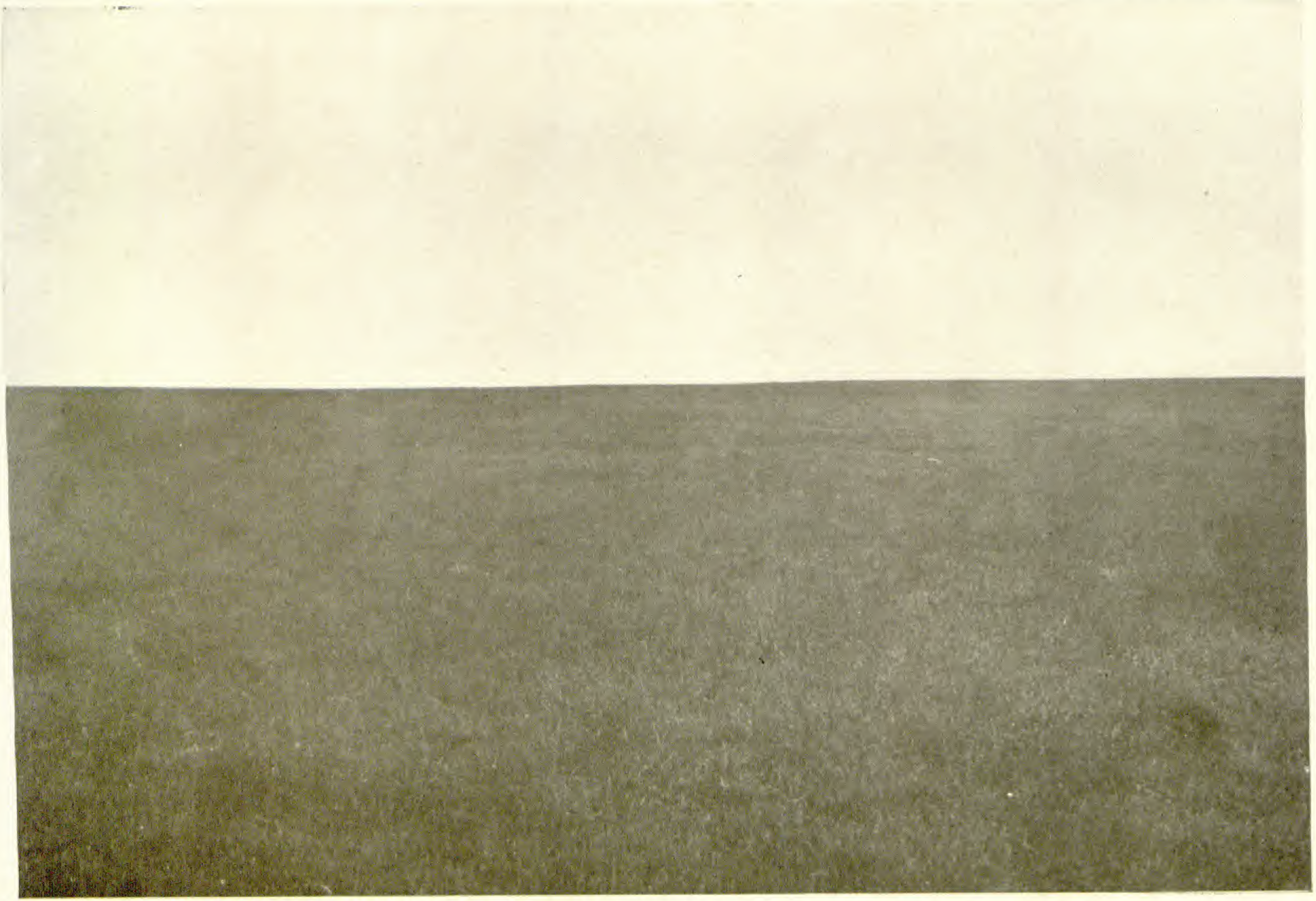
EXPLANATION OF PLATE 7

Looking southeast in dry valley at head of Hempstead Brook, about 1½ miles east of Garden City, showing treeless horizon about ¼ mile away. The view embraces a horizontal angle of about 40°. (There was no house within a mile of this spot, but if the camera—which was about four feet from the ground—had been raised a few feet, some buildings and planted trees would have appeared in the view.) Taken in a gentle rain at 4 p.m., Oct. 27, 1907. (For other views taken near the same place see Bull. Am. Geog. Soc. **43**: 352; Torreya **12**: 279. The most conspicuous plant in the foreground of the former, not there designated, is ***Eupatorium hyssopifolium***.) Ten years later this place was included in the site of Camp Mills, and its appearance greatly altered; so that there will probably never again be an opportunity to take such a photograph on Long Island.

ADDENDA (March, 1918)

P. 276. The tradition is, Mr. Henry Hicks tells me, that a century or more ago a man crossing the Plains on horseback on a dewy morning would be wet to his waist; which seems to indicate that much of the grass was five or six feet tall. This is not at all improbable, for a news item in a Kansas City paper of Oct. 27, 1915, reports blue-stem grass (*Andropogon furcatus*) growing to a height of 9½ feet in Chase County, Kansas.

Pp. 276, 284. Both Hempstead Brook and East Meadow Brook within the prairie area are dry most of the time now, a considerable change having taken place in that respect within the writer's recollection, perhaps on account of the lowering of the ground-water about their sources by pumping from deep wells to supply the rapidly growing villages.



PRAIRIE AT HEAD OF HEMPSTEAD BROOK, LONG ISLAND

A STUDY OF SOME FACTORS INFLUENCING THE STIMULATIVE ACTION OF ZINC SULPHATE ON THE GROWTH OF ASPERGILLUS NIGER. I. THE EFFECT OF THE PRESENCE OF ZINC IN THE CULTURAL FLASKS

By R. A. Steinberg

Columbia University

The increased growth of *Aspergillus niger* resulting from the introduction of zinc salts into the nutrient solution was first observed by Raulin (9). This observation was confirmed by Richards (10) in 1897, who noted also that other elements (Co, Ni, F, Fe, etc.) exercised an influence similar to that of zinc.

The studies of these two investigators, as well as those of Ono (8), of Richter (11), and of others agree in that there is the greater growth in the presence of zinc, although the percentage increase the various authors obtained is not identical.

In 1903, however, a publication by Coupin (2) appeared, in which this author came to the conclusion that the increased dry weights formed in cultures of *Aspergillus niger* through the addition of zinc salts takes place only in impure cultures. The addition of zinc is effective, in this investigator's opinion, only in those cases in which there is an opportunity for the suppression of the activities of other organisms, whose presence in the *Aspergillus niger* cultures prevents the full development of this fungus. In pure cultures the maximum dry weight is obtained without the addition of zinc.

Another interpretation of Coupin's results has been suggested by Javillier (3)—namely, the introduction of zinc into the nutrient liquid through solution of constituents of the glass of the cultural flask. Javillier, indeed, states that with cultures in Jena glass (flasks of the same kind of glass were made use of by Coupin) the addition of zinc is unnecessary inasmuch as the maximum growth (about 1 gram per 50 c.c. nutrient solution) takes place. Simultaneous cultures in Kavalier Bohemian and quartz flasks did not exceed a yield of about 0.3 grams per 50 c.c. nutrient solution unless zinc was added.

According to Lepierre (5, 6), on the other hand, the increased yields obtained by Coupin should be ascribed to the excessive volume of nutrient solution employed as compared to the volume of the containing flask. The increased depth of the solution, he assumes, results in decreased aëration of the cultures and increased growth ensues. Zinc, it is stated by Lepierre (6), could be found neither in the flasks (whether Jena or Kavalier is not stated) or compounds used nor in the fungal membranes.

Javillier (4), in repeating Lepierre's experiments in Kavalier glass, did not succeed in obtaining an essential variation in the yield by varying the ratio of surface to volume.

It is interesting to note in this connection that the presence of zinc in Jena glass has frequently been reported in the literature, more recently through the analyses of Nicolardot (7) and of Walker and Smither (12). Moreover, Kavalier Bohemian glass according to the same authors is free from zinc.

That the composition of the cultural flasks is of importance and that both the rate of growth and the fructification of *Aspergillus niger* can be influenced by solution of components of the glass has been claimed by Benecke (1).

To obtain, if possible, additional evidence as to whether cultures of *A. niger* to which no zinc has been intentionally added attain a greater growth in Jena glass than in Kavalier Bohemian, I have grown parallel cultures in these two glasses, and in addition, a third glass, Pyrex. Zinc according to Walker and Smither (12) does not enter into the composition of Pyrex glass.

In the experiments whose description follows the Pfeffer nutrient solution has been used (10).

PFEFFER SOLUTION

	Grams
Water	1000.0
Cane sugar	50.0
Ammonium nitrate	10.0
Mono-potassium phosphate	5.0
Magnesium sulphate	2.5
Iron sulphate	trace

The compounds employed in the preparation of this solution were water redistilled through glass; Merck's "Reagent" ammonium nitrate and magnesium sulphate; Kahlbaum's "Zur anal." magnesium sulphate; and Baker's "Analyzed" potassium phosphate, ferric sulphate, and zinc sulphate. The cane sugar used is that sold under the proprietary name of "Crystal Domino" sugar. This solution was prepared as needed.

The flasks used were: 200 c.c. Jena and 150 c.c. Pyrex Erlenmeyer's; and 250 c.c. Kavalier Bohemian Florence flasks. They were cleaned by rinsing with concentrated sulphuric acid, tap-water, lastly distilled water, and inverted to drain dry. The precaution was taken of reserving part of the flasks for zinc-free cultures and part for zinc cultures only, though this performance is unnecessary, as the following indicates:

1. ON THE EFFICIENCY OF THE METHOD FOR CLEANING THE CULTURAL FLASKS

Pfeffer solution: water redistilled through glass; "Crystal Domino" sucrose; NH_4NO_3 (Merck); KH_2PO_4 (Baker); $MgSO_4 \cdot 7H_2O$ (Kahlbaum). Temperature 30–31° C. Period of growth 7 days. No zinc added. Pyrex flasks.

Flasks reserved for zinc-free cultures	Flasks reserved for zinc cultures
0.924 grams*	0.283 grams
0.336 "	0.265 "
0.321 "	0.313 "
0.328 "	0.341 "
0.355 "	0.352 "
0.335 "	0.311 "

The flasks in the second column were previous to this experiment used three consecutive times for cultures containing 10 mg. Zn/L. and were cleaned as usual.

Zinc was added where indicated to the entire solution used in the preparation of cultures having the same concentration of this heavy metal and not to the individual flasks. The stock solu-

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* High yield, due probably to the accidental introduction of zinc. This value not included in the average. In at least one case it was noted that the same Pyrex flask consistently gave cultures having a high yield, though the addition of zinc was omitted.

tion contained 2.5 mg. zinc per cubic centimeter (i. e., 11.0 mg. $ZnSO_4 7.H_2O$ per c.c.).

The flasks, each containing 50 c.c. of nutrient solution measured in a 50 c.c. graduate, were sterilized at 14½ lbs. for 20 minutes.

Inoculations were from stock bread-cultures grown at room temperature (18–25° C.). Enough spores were added with a platinum loop to make a visible and apparently almost continuous layer on the solution surface. The *A. niger* culture used in these experiments was obtained originally from the "Internationalstelle für Pilz-Kulturen, Amsterdam." Immediately after inoculation the flasks were placed in a dark cupboard at room temperature (18–23° C.), or in the thermostat at 30–31 ° C.

When harvested, the membrane, together with the solution, was thrown on a washed and weighed filter, washed with distilled water and dried at 103–105° C. for four days.

The yields while given to the third place are probably reliable to two places only.

2. THE EFFECT OF ADDING ZINC TO THE CULTURE MEDIUM

Pfeffer solution: water redistilled through glass; "Crystal Domino" sucrose; NH_4NO_3 (Merck); KH_2PO_4 (Baker); $MgSO_4.7H_2O$ (Merck). Room temperature (18–23° C.). Period of growth ten days.

Kavalier Bohemian		Pyrex	
No zinc	10 mg. Zn/L	No zinc	10 mg. Zn/L
0.317 grams	0.888 grams	0.387 grams	0.864 grams
0.330 "	0.905 "	0.328 "	0.855 "
0.341 "	0.886 "	0.306 "	0.878 "
0.302 "	0.880 "	0.286 "	0.868 "
0.314 "	0.924 "	0.325 "	0.903 "
0.321 "	0.897 "	0.326 "	0.874 "

Here we see that in the Kavalier and Pyrex flasks the addition of zinc to the nutrient solution results in an increased dry weight, the increase being almost three-fold.

3. THE INFLUENCE OF A ZINC GLASS (JENA) ON THE YIELD

Pfeffer solution: water redistilled through glass; "Crystal Domino" sucrose; NH_4NO_3 (Merck); KH_2PO_4 (Baker); $MgSO_4$.-

$7H_2O$ (Kahlbaum). Room temperature (18–23° C.). Period of growth ten days.

Jena		Kavalier Bohemian		Pyrex	
No zinc	10 mg. Zn/L	No zinc	10 mg. Zn/L	No zinc	10 mg. Zn/L
0.989 gr.	0.980 gr.	0.270 gr.	0.924 gr.	0.319 gr.	0.940 gr.
0.958 "	0.940 "	0.299 "	0.943 "	0.248 "	0.980 "
0.919 "	1.005 "	0.285 "	0.886 "	0.306 "	0.917 "
0.933 "	0.988 "	0.300 "	0.947 "	0.252 "	0.952 "
0.953 "	1.022 "	0.351 "	1.017 "	0.309 "	0.997 "
0.950 "	0.987 "	0.301 "	0.943 "	0.287 "	0.957 "

With nutrient solutions to which no zinc has been added a distinct difference is displayed, as concerns the yield, between the Jena flasks, on the one hand, and the Kavalier and Pyrex on the other. The low yields characteristic of the zinc-free culture are obtained only in the latter two glasses.

Cultures grown in the presence of 10 mg. zinc (calculated as metal) per liter attained a dry weight of approximately one gram irrespective of the kind of flask used.

Additional experiments bringing out the increased growth taking place in a culture medium to which no zinc has been intentionally added when in Jena glass are as follows:

4. THE INFLUENCE OF A ZINC GLASS (JENA) ON THE YIELD

Pfeffer solution: water redistilled through glass; "Crystal Domino" sucrose; NH_4NO_3 (Merck); KH_2PO_4 (Baker); $MgSO_4$.$7H_2O$ (Kahlbaum). Temperature 30–31° C. Period of growth seven days. No zinc added.

Pyrex	Jena
0.247 grams	0.948 grams
0.232 "	0.896 "
0.327 "	0.893 "
0.279 "	0.904 "
0.257 "	0.904 "
0.268 "	0.909 "

5. CONDITIONS AS IN THE PRECEDING EXPERIMENT

Pyrex	Jena
0.336 grams	0.915 grams
0.316 "	0.849 "
0.376 "	0.881 "
0.332 "	0.872 "
0.296 "	0.864 "
0.331 "	0.876 "

Here also we see that while addition of zinc is necessary to bring about increased growth in Pyrex flasks, this increase in growth occurs in the cultures in Jena glass to which no zinc has been intentionally added.

A comparison of the values obtained in these experiments will show the agreement in the dry weights of individual duplicate cultures, and of the mean values (average of five duplicate cultures) obtained in the different experiments. On the average the deviation from the mean does not exceed 0.040–0.050 gram, in exceptional instances deviations of as much as 0.10–0.15 gram being encountered. This means, therefore, a variation of about 5 per cent for the zinc cultures and of 15 per cent for the zinc-free cultures, since the mean weight of the former is about 0.95 grams, of the latter 0.30 grams.

We are therefore justified in concluding that while the addition of zinc serves to bring about an increased formation of dry weight in Kavalier Bohemian and Pyrex flasks, such increased formation of dry weight takes place in Jena flasks to which no zinc is intentionally added. That the increased growth that occurs in the Jena flasks is due to the solution of small amounts of zinc from the flasks is also highly probable in view of the presence of zinc in this glass.

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TWO MONTHS IN THE SOUTHERN CATSKILLS

By Oliver P. Medsger

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During the summer of 1914, the writer spent ten days at Woodland, New York, as the guest of Mr. H. W. Little, the director of "Camp Wake Robin," one of the oldest and best known of the boys' camps in the East. Much of the time was spent in getting acquainted with the flora of the region. This year (1917) he accepted the position as councilor and director of nature study in the camp and spent from June 30 to August 30 there. Although some attention was given to birds and insects, yet ample time was available for a further study of the flora.

The writer was not the first Torreyite to collect and study in this region. We find in the register of the Roxmor hotel at Woodland a record of a field meeting of the Torrey Botanical Club, June 2, 1901. Members who stopped at the hotel were Fanny A. Mulford, Heloise G. Esterly, N. L. Britton, Mrs. Britton, Anna Murray Vail, Alexandrina Taylor, E. P. Bicknell, and C. L. Pollard. It is not often that so many distinguished botanists attend a field meeting of the Torrey or any other botanical club. Mr. Edward Miller, the proprietor of the hotel at Woodland, is a former member of the Torrey Club and took much interest in our botanical work. Mr. Bicknell must be very familiar with the region, for it was in 1880, on Slide Mountain, that he discovered the thrush that bears his name. To me it was a great pleasure while camping on Slide Mountain to listen to the fine flute-like strains of this bird.

Woodland is situated in Ulster County, about four miles south of Phoenicia, in the heart of the southern Catskills. It has an altitude of about 1,000 feet. Many of the highest peaks are in full view. In the narrow valley flows Woodland Brook, one of the finest and most beautiful of all the streams in the Catskill region. The eminent naturalist, John Burroughs, on returning from a trip to the summit of Wittenberg, remarked: "The trail to which we had committed ourselves led us down into Woodland valley, a retreat which so took my eye by its fine trout brook, its superb mountain scenery and its sweet seclusion, that I marked it for my own." Elsewhere, Mr. Burroughs speaks of this immediate locality: "Of all the retreats I have found amid the Catskills, there is no other that possesses quite so many charms for me as this valley; it is so wild, so quiet, and has such superb mountain views."

The rocks of the region are practically all of sandstone of the Devonian period. The tops of the mountains are capped with a coarse conglomerate which apparently disintegrates easily; thus the soil, as a general thing, is sandy or gravelly. Loose stones abound almost everywhere, either the result of glacial action or of weathering. The mountains are steeper and rougher and the valleys narrower and deeper than they are in the northern Catskills.

Every week we took a hike with the camp boys to some interesting locality. We spent on each trip from one to three days. The region around Woodland for a radius of nearly ten miles was fairly well covered. Among the mountains visited were Terrace, Wittenberg, Cornell, Slide, The Giant's Ledge, Cross Mountain, and Mt. Pleasant. We also collected plants about Winnesook, along the Panther Kill, at Diamond Notch, in the West Kill Valley, at the Broad Hollow Notch, and about Shandakin. Slide Mountain is the highest peak of the Catskills and we found it a most interesting region botanically.

Almost the entire area is covered with forests. Years ago, some of the best timber was cut away and a surprising waste in wood took place. Hemlock trees by the thousands were felled for the bark, which is extensively used for tanning, and the logs were allowed to decay on the ground. This was probably the most abundant tree of the neighborhood, now it is scarcely common. It was about the time of the Civil War that the greatest destruction of this tree occurred. Where trees were cut for lumber, very wasteful methods were used. Sometimes, as on Cornell Mountain, one may find a virgin forest of rare beauty. It is always a delight these days to find such a forest in the East. All the higher mountains of this region are in the State Forest Reserve. This reservation includes practically everything above an altitude of 1,500 feet.

About forty-five species of native trees were found. Undoubtedly the most abundant tree of the neighborhood is the yellow birch, *Betula lutea.* To a great extent it is taking the place of the hemlock. In some localities one sees scarcely anything else. A few beautiful specimens of the paper birch were observed. Their chalky whiteness could be seen from afar. The sweet or black birch, *Betula lenta*, is common. In July, when the American chestnut was in bloom, many fine trees were seen about Woodland. This tree extended up the mountain side to an altitude of about 1,500 feet. The chestnut-tree blight, so destructive in many localities, reached that part of the Catskills this year for the first time. During the latter part of August, its ravages could be plainly seen.

Oaks are scarce in that locality. A few good trees of the red oak were observed in the vicinity of Woodland. The black oak is the only other *Quercus* that we came across. Hickories are also rather scarce, only a few trees being found. Among the more common trees growing there are the American beech, American hornbeam (*Carpinus caroliniana*), American aspen (*Populus tremuloides*), large-toothed aspen (*Populus grandidentata*), American linden, white ash, sugar maple, mountain maple, red maple, witch hazel, American elm, and slippery elm. The serviceberry (*Amelanchier canadensis*) is quite common and has finer fruits than it has in any other locality where I have found it. A few fine specimens of the butternut (*Juglans cinerea*) are growing in the lowlands about Woodland. At an altitude of about 2,000 feet, the striped or goosefoot maple is quite common. Some of the trees are forty feet high with trunk diameters of six to eight inches.

The white pine is a common tree about Woodland and Phoenicia. Many of the smaller trees are attacked by the white-pine weevil, *Pissodes Strobi* Peck. The attack in almost every case is made on the central axis about three feet from the top, causing it to die. We found no evidence of the white-pine blister rust.

On the summits of the mountains, evergreens predominate. On Wittenberg and Slide mountains, the balsam fir (*Abies balsamea*) is the chief tree. Near the summit of the former mountain are almost impenetrable forests of this tree. On Wittenberg are also to be found the black spruce and a few small trees of the red spruce. Cornell Mountain, which is one of the highest peaks of the Catskills, reaching an elevation of 3,900 feet, has its top and west side covered with a heavy virgin forest of red spruce (*Picea rubra*). Viewed from the summit of Slide Mountain, this beautiful forest appears to cover several square miles. Scarcely any other species grow in this area and its boundaries are very definite. It is almost inaccessible to the lumbermen. The trees are tall and straight, many of them attaining a diameter of two feet or more.

The mountain ash is a common tree on Slide and some of the other mountains. This year its large fruit-clusters were well developed. Judging from the variation in the leaves, both *Sorbus americana* and *Sorbus sambucifolia* probably exist in this locality. This will be a question for further investigation.

Thirty species of ferns were collected. The most abundant were the hay-scented fern, *Dennstaedtia punctilobula*, and the spinulose shield-fern, *Dryopteris spinulosa*. A coarse variety of the latter fern is found near the summit of Slide Mountain. The intermediate variety is especially abundant along the northeast base of Slide, where it grows with *Lycopodium lucidulum*. The two often nearly cover the ground. Nowhere else in the country have we found this club moss so plentiful. Among the rarer ferns observed were *Botrychium lanceolatum*, *Camptosorus rhizophyllus*, *Matteuccia Struthiopteris* (of which only one station is known in the locality we studied), and *Dryopteris Braunii*. The last-named fern was of especial interest to us, for the specimens were the first we had seen outside of the herbarium. We first found it on the east side of Mount Pleasant, where it was growing with *Dryopteris Goldieana*. We afterward found many plants of it growing along the trail to Wittenberg at an altitude of about 1,500 feet. It is graceful, distinct, and certainly one of the most beautiful of all our eastern species.

Inasmuch as nine tenths of the region studied is covered with woodland, weeds and foreign plants generally are not plentiful. However, two of these are especially abundant. One is *Echium vulgare,* commonly known as blueweed or viper's bugloss. Its bright blue flowers were conspicuous all along the roadside from Phoenicia to Woodland. The other plant referred to is *Origanum vulgare* or wild marjoram, also a native of Europe. It grows in great abundance in almost all the cleared or waste land about Woodland, often so plentiful as to exclude other plant life. As it grew everywhere about the hotel, its purple bracts, conspicuous blossoms and strong mint odor brought forth many inquiries concerning it.

It is always interesting to note the succession of plants and trees as one ascends a mountain. This we especially observed in going to the summits of Wittenberg, Cornell, and Slide. The trail to Wittenberg first leads up the northeast side of Terrace Mountain, which is covered with a dense forest, in which the most abundant tree is yellow birch. The chestnut, beech, and other trees of low elevation are soon left behind. The shrub most common is hobble-bush, *Viburnum alnifolium.* It seems rather strange to find this plant in such abundance, for one rarely sees it fruit in these dense woodlands. At about 1,800 feet *Acer pennsylvanicum* appears. The dry glaciated top of Terrace is reached at an altitude of 2,300 feet. Here amid the rocks and boulders, the blueberries of two or three species grow in great abundance. There are also a few small scattered trees of balsam fir and black spruce. The mountain ash also appears for the first time. Probably the most conspicuous plant on Terrace is *Clintonia borealis.* It grew everywhere along the trail, about the rocks and in fact in any place where it could get a chance to grow. What a pity its large blue berries are not edible, for gallons of them could have been gathered. *Clintonia umbellulata,* which is common in Woodland valley, is also occasionally found here.

As we leave Terrace to continue the trail to the summit of Wittenberg, we begin to find *Trillium undulatum,* with its bright red berries filled with seeds. This plant is most numerous at an altitude of about 2,500 feet. At 3,000 feet the ground hemlock or American yew, *Taxus minor,* becomes plentiful. This small conifer sometimes nearly covers the ground. We next came across the creeping snowberry, *Chiogenes hispidula*, with its snow-white berries and strong odor of wintergreen. Deciduous trees are getting fewer, while the fir and the spruce are becoming more abundant. From 3,000 to 3,700 feet the mountain is steep and the trail is difficult to follow. Soft moss generally covers the ground and often the trunks and branches of the fir trees are covered with moss to their very tops. The sun shines but a few hours a day on this, the north side of the mountain. Nowhere else have we seen the common polypody fern grow in such perfection as on Wittenberg and Cornell mountains.

Probably the most conspicuous plant on the summit of Wittenberg, which has an elevation of about 3,900 feet, is *Aralia hispida*. Most of the plants had just finished blooming and small green berries were forming. On the morning of that same day, August 25, we found a cluster of these plants in Woodland valley, where the berries were dark purple, ripe, and many of them had either fallen off or had been eaten by the birds. This plant looks much more like an umbellifer than do the other species of the genus and the immature plant is apt to be mistaken for one. On the very summit of Wittenberg, the most interesting shrub to us is *Ilicioides mucronata* or mountain holly. Heretofore we have seen this shrub only in mountain swamps, and were surprised to find it on the dry summit of Wittenberg. Growing in the open, the shrub developed a fine globular form with somewhat pendent branches containing numerous red berries. It would be a splendid thing in cultivation if it could be induced to grow on moderately dry soil.

We spent the night on Wittenberg and had the great pleasure of seeing the aurora borealis as it is generally pictured in books. Great luminous streams flared up in the northern sky extending well toward the zenith. They were ever changing yet always beautiful. The phenomena lasted for nearly an hour. From Wittenberg, we went to the summit of Cornell which is just a little less than 4,000 feet in altitude. This mountain is covered with trees. We went down the west side of Cornell through this beautiful virgin forest of red spruce, crossed a flat strewn with boulders and at an elevation of probably 3,000 feet began to ascend the eastern slope of Slide. Here against the sunny incline, the wild red raspberry, *Rubus strigosus*, grows with much larger stalks and finer, larger berries than in Woodland valley, where it is so plentiful. The eastern slope of Slide is very steep and difficult to climb, but we finally reached the summit. This is the highest of all the Catskill range, with an altitude of about 4,250 feet. The trees are mostly balsam fir. On the very highest part of Slide, the ground is often entirely covered with *Cornus canadensis*, the dwarf cornel or bunchberry. Its beautiful green leaves bedecked with bunches of bright red berries made one of the most pleasing botanical sights we have ever witnessed.

It is surprising how many bog plants and plants that grow in cool, damp places are to be found on the dry summits of these mountains. The probable causes are that there is more precipitation on mountain tops, that it is cooler, the warm season is shorter, and evaporation is less, so that during the greater part of the year the soil is quite moist.

I have presented but a few of the botanical conditions of this interesting region and hope that the future will give opportunity for a more exhaustive study.

A PRELIMINARY REPORT ON THE RUSSULAE OF LONG ISLAND

By Gertrude S. Burlingham

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Field work on the genus *Russula* on Long Island has been limited to a region on the northern shore reaching from Cold Spring Harbor to Port Jefferson. The first collections of which we have published record were made by the state botanist, Dr. Charles H. Peck, near Port Jefferson. As a result of this work he described three new species of *Russula* in the State Museum Bulletin, number 50, published in 1897. In August, 1902, Dr. Peck, in company with Professor F. S. Earle, continued the search for fleshy fungi in the vicinity of Port Jefferson and Smithtown. From these collections two new species of *Russula* were described by Dr. Peck the following year in the sixty-seventh Bulletin of the State Museum. In 1909 Professor C. H. Kauffman described one new species, *Russula sphagnophila*, from Cold Spring Harbor. In the summer of 1912 I spent July and the early part of August at Cold Spring Harbor studying the *Russulae* and *Lactariae* of the locality. Although the season was unusually dry, I was able to secure 23 different species of *Russula*, four of which were undescribed.

In all, thirty-six species of *Russula* have been identified from Long Island, of which fourteen are European species and twenty-two American species. Nine of the latter have their type locality near Port Jefferson or Cold Spring Harbor. The European species reported from this region have a distribution in the United States both to the north and the south of Long Island. Of the American species eight, *R. albida* Peck, *R. compacta* Peck, *R. crustosa* Peck, *R. flavida* Frost, *R. Mariae* Peck, *R. subvelutina* Peck, *R. uncialis* Peck, *R. variata* Bann. & Peck, have a distribution from New England to Virginia, North Carolina, or Alabama. On the other hand, the distribution of three species, *R. albella* Peck, *R. Earlei*

Peck, and *R. pusilla* Peck, seems to extend toward the south only; while *R. betulina* Burl., *R. flaviceps* Peck, and *R. serissima* Peck have been reported from Long Island to the northward only. Of the type species from Long Island, *R. anomala* Peck, *R. magnifica* Peck, and *R. sphagnophila* Kauff. have been found only in the type locality. Although *R. blanda* Burl. has been found only at Cold Spring Harbor, several collections have been made in different localities and during different seasons.

One of the most abundant species of *Russula* found at Cold Spring Harbor was *R. Mariae* Peck. It grew in woods, by wooded roadsides, or even in the middle of sandy unfrequented roads. *R. pectinata* Peck, although not so widely distributed as *R. Mariae* Peck, occurred in abundance wherever found. One species resembling *R. decolorans* Fr. in some respects but with the wounded flesh turning red then gray is identical with an unpublished new species which Professor H. C. Beardslee has in manuscript.

The species referred to *R. obscura* Romell is very probably *R. rubescens* Beards. I am more inclined to this opinion because this autumn I have collected this on Staten Island and have seen fresh specimens of it from White Plains, N. Y. In fact since I began critical examination of the wounds of specimens resembling *R. obscura* Romell, I have seen none the wounds of which did not turn red as in *R. rubescens* Beards. When this was described in 1914 it was known only from the type locality. But since then it has been found in abundance around Boston, and in Newfane, Vermont.

The region included between Port Jefferson and Cold Spring Harbor lies in the part of Long Island covered with ice at the Ronkonkoma stage, and the soil is of a sandy or stony loam, and gravel structure. The woods are composed of mixed hardwoods with an abundance of oaks intermingled with chestnuts. It is possible that the seemingly limited distribution of certain species, and the apparent southern or northern distribution of others is due to lack of extensive field work or the rare occurrence of these species. On the other hand the character of the soil and the forest types may determine the southern or northern limit of distribution. Except as temperature affects the forest type it is not probable that it affects the distribution of the *Russulae* on Long Island.

The work on this genus on Long Island has been only begun. It is probable that double the number of species found may yet be discovered when the work of collecting has been extended to the outwash plains toward the south and to the pine-bearing regions. The work thus far done has shown that we may expect to find not only those species ranging from New England to Virginia and southward, but some southern species which reach their northern limit in the latitude of New York, and certain northern species which extend their southern limit to Long Island. And it is possible that some species may prove to be found exclusively on Long Island.

AMERICAN SPECIES OF RUSSULA OCCURRING ON LONG ISLAND

1. RUSSULA ALBELLA Peck, Ann. Rep. N. Y. State Mus. **50**: 101. 1897.

Port Jefferson, Long Island, *Peck & Earle 812*, in herb. N. Y. Bot. Garden. This is the type locality of the species. It occurs in dry soil in deciduous woods. Its distribution in the United States extends south as far as Mississippi.

2. RUSSULA ANOMALA Peck, Ann. Rep. N. Y. State Mus. **50**: 99. 1897.

Only the type material of this has been found. It was collected at Port Jefferson, on damp ground under trees.

3. RUSSULA ALBIDA Peck, Bull. N. Y. State Mus. **1**^{2}: 10. 1888.

Suffolk County, Long Island, *Peck*. The specimens are in the herbarium of the State Museum at Albany.

4. RUSSULA BETULINA Burl. N. Am. Fl. **9**: 227. 1915.

Port Jefferson, *Peck & Earle 805*, in herb. N. Y. Bot. Garden. The collection was made Aug. 5, 1902.

5. RUSSULA BLANDA Burl. N. Am. Fl. **9**: 213. 1915.

Cold Spring Harbor, type, *24*, 1912, in herb. Burl., extype, herb. N. Y. Bot. Garden and the Brooklyn Bot. Garden.

6. RUSSULA COMPACTA Frost & Peck; Peck, Ann. Rep. N. Y. State Mus. **32**: 32. 1880.

The specimens of this were collected by Peck in Suffolk County and reported in the N. Y. State Mus. Bull. **116**: 72. 1906.

7. RUSSULA CRUSTOSA Peck, Ann. Rep. N. Y. State Mus. **39**: 41. 1887.

Port Jefferson, *Peck & Earle 821*, in herb. N. Y. Bot. Garden; Cold Spring Harbor, *Burlingham.*

8. RUSSULA EARLEI Peck, Bull. N. Y. State Mus. **67**: 24. 1903.

Port Jefferson, *Peck & Earle 843*, type material in herb. N. Y. Bot. Garden, col. Aug. 6, 1902; also *878*, in herb. N. Y. Bot. Garden, col. Aug. 2, 1902; Smithtown, *Peck & Earle 914*, herb. N. Y. Bot. Garden, col. Aug. 8, 1902.

9. RUSSULA FLAVICEPS Peck, Ann. Rep. N. Y. State Mus. **53**: 843. 1900.

Cold Spring Harbor, *Burlingham 45*, 1912.

10. RUSSULA FLAVIDA Frost & Peck; Peck, Ann. Rep. N. Y. State Mus. **32**: 32. 1880.

Port Jefferson, *Peck & Earle 884*, in herb. N. Y. Bot. Garden, col. Aug. 2, 1902.

11. RUSSULA HUMIDICOLA Burl. N. Am. Fl. **9**: 230. 1915.

Cold Spring Harbor, *Burlingham 20*, 1912, type. Abundant in thoroughly moist soil in woods. This has also been found in Massachusetts.

12. RUSSULA MAGNIFICA Peck, Bull. N. Y. State Mus. **67**: 24. 1903.

Port Jefferson, *Peck & Earle 841*, in herb. N. Y. Bot. Garden, col. Aug. 6, 1902. Thus far this species has not been reported from any other region.

13. RUSSULA MARIAE Peck, Ann. Rep. N. Y. State Mus. **24**: 74. 1872.

Cold Spring Harbor, *Burlingham.* Very abundant.

14. RUSSULA MODESTA Peck, Bull. N. Y. State Mus. **116**: 78. 1907.

Cold Spring Harbor, *Burlingham 52*, 1912.

15. RUSSULA PUSILLA Peck, Ann. Rep. N. Y. State Mus. **50**: 99. 1897.

Suffolk County, *Peck*, type material; Cold Spring Harbor, *Burlingham 50*, 1912.

16. RUSSULA SERISSIMA Peck, Bull. N. Y. State Mus. **139**: 44. 1910.

Cold Spring Harbor, *Burlingham 100*, 1912, August 3, 1912.

17. RUSSULA SPHAGNOPHILA Kauffman, Rep. Mich. Acad. Sci. **11**: 86. 1909.

Cold Spring Harbor, type locality, collected by C. H. Kauffman. Distribution limited to the type locality.

18. RUSSULA SUBVELUTINA Peck, Bull. Torrey Club **33**: 215. 1906.

Port Jefferson, *Peck & Earle 871*, in herb. N. Y. Bot. Garden, col. Aug. 6, 1902.

19. RUSSULA UNCIALIS Peck, Bull. N. Y. State Mus. **1**^{2}: 10. 1888.

Cold Spring Harbor, *Burlingham 91*, 1912. In moist oak and chestnut woods, Aug. 3, 1912.

20. RUSSULA VARIATA Bann. & Peck; Peck, Bull. N. Y. State Mus. **105**: 41. 1906.

Port Jefferson, *Peck & Earle 853*, in herb. N. Y. Bot. Garden; Cold Spring Harbor, *Burlingham.*

21. RUSSULA VINACEA Burl. N. Am. Fl. **9**: 217. 1915.

Cold Spring Harbor, *Burlingham 85*, 1912, type; *86*, 1912; *97*, 1912. Abundant in wet woods of oak and chestnut in early August. This species occurs also on Staten Island and in New Jersey.

22. RUSSULA CINERASCENS Beardslee (in manuscript).

Cold Spring Harbor, *Burlingham.*

EUROPEAN SPECIES OF RUSSULA FOUND ON LONG ISLAND

23. RUSSULA AERUGINEA Lindbl.; Fries, Monog. Hymen. Suec. **2**: 198. 1863.

Cold Spring Harbor, *Burlingham 99*, 1912, Aug. 3, 1912.

24. RUSSULA DECOLORANS Fries, Epicr. Myc. 361. 1838.

Cold Spring Harbor, *Burlingham.* In wet woods of oak, chestnut, and red maple, Aug. 3, 1912.

25. RUSSULA DELICA Fries, Epicr. Myc. 350. 1838.

Cold Spring Harbor, *Burlingham.*

26. RUSSULA DENSIFOLIA (Secr.) Gill. Champ. Fr. 231. 1876.

Suffolk County, *Peck*, as reported in Bull. N. Y. State Mus. **116**: 70. 1906.

27. RUSSULA EMETICA (Schaeff.) Pers. Obs. Myc. **1**: 100. 1796.

Cold Spring Harbor, *Burlingham.* In moist woods on decaying log.

28. RUSSULA FLAVA Lindbl. Nord. Svampb. 27. 1895.

Port Jefferson, *Peck & Earle 828*, Aug. 5, 1902.

29. RUSSULA FOETENS (Pers.) Fries, Epicr. Myc. 359. 1838.

Cold Spring Harbor, *Burlingham 41*, 1912.

30. RUSSULA FRAGILIFORMIS Burl., Mycologia **8**: 312. 1916.

Russula fragilis Fries, Epicr. Myc. 359. 1838.

Cold Spring Harbor, *Burlingham*, July 5, 1912.

31. RUSSULA HETEROPHYLLA Fries, Epicr. Myc. 352. 1838.

Cold Spring Harbor, *Burlingham.*

32. RUSSULA LEPIDA Fries, Sv. Aetl. Svamp. 50. 1836.

Port Jefferson, *Peck & Earle 854*, Aug. 6, 1902, and *887*, Aug. 7, 1902, in herb. N. Y. Bot. Garden.

33. RUSSULA OBSCURA Romell, Oefv. Sv. Vet.-Akad. Förh. **48**: 179. 1891.

Cold Spring Harbor, *Burlingham 90*, 1912, Aug. 3, 1912. This is very possibly *R. rubescens* Beardslee. It is impossible to distinguish some of the dark specimens of *R. rubescens* from the typical *R. obscura*. Beardslee did not describe his species until 1914 and prior to that time no notes had been made of the flesh of red forms of *Russula* changing to red when wounded. The only way to distinguish these two positively is to observe the change in the wounds of fresh plants.

34. RUSSULA PECTINATA Fries, Epicr. Myc. 358. 1838.

Cold Spring Harbor, *Burlingham 42*, 1912. Very abundant in sandy soil. This is probably the species which Dr. Peck referred to *R. sororia* Fries, Bull. N. Y. State Mus. **116**: 84. 1907.

35. RUSSULA PURPURINA Quél. & Schulz.; Schulzer, Hedwigia **24**: 139. 1885.

Cold Spring Harbor, *Burlingham 75*, 1912. Moist woods, August.

36. RUSSULA SUBOLIVASCENS Burl. N. Am. Fl. **9**: 223. 1915.

Russula olivascens Fries, Epicr. Myc. 361. 1838.

Port Jefferson, *Peck & Earle 852*, in herb. N. Y. Bot. Garden, col. Aug. 6, 1902.

DOUBTFUL SPECIES

RUSSULA RUBRA Fries, Epicr. Myc. 354. 1838.

Suffolk County, *Peck*. Reported in Bull. N. Y. State Mus. **116**: 79. 1907.

ON THE OSMOTIC CONCENTRATION OF THE TISSUE FLUIDS OF DESERT LORANTHACEAE*

By J. Arthur Harris

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I. Introductory remarks

In an earlier publication Mr. Lawrence and I† discussed a series of determinations of the osmotic concentration of the tissue fluids of Jamaican montane rain-forest Loranthaceae parasitic on various hosts. The purpose of this paper is to present the results of studies of the sap concentration of the tissue fluids of desert mistletoes and of that of their host plants for comparison with the rain-forest series already published.

The number of determinations upon which the conclusions of the present paper is based is not so large as that which Mr. Lawrence and I were able to obtain in Jamaica. In explanation I may merely say that the difficulties under which the desert series was secured were far greater‡ than those which surrounded the work in the Blue Mountains. This has necessarily restricted the number of determinations, and notwithstanding our best

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* Coöperative investigations carried out under the auspices of the Department of Botanical Research and the Department of Experimental Evolution, of the Carnegie Institution of Washington.

I am greatly indebted to Mr. P. C. Standley, of the United States National Herbarium, for identifying these and other Arizona plants. Dr. Trelease, whose splendid monograph of the genus *Phoradendron* has recently appeared, has kindly gone over the parasites.

† Harris, J. Arthur, & Lawrence, John V. On the osmotic pressure of the tissue fluids of Jamaican Loranthaceae parasitic on various hosts. Am. Jour. Bot. **3**: 438–455. 1916.

‡ I am greatly indebted to the director and the staff of the Desert Laboratory for every facility that could be given for these studies. The difficulties were such as are inseparable from physiological work in camp under summer conditions in the Southwestern deserts. For example, the torrential rains, which are characteristic of the region during the midsummer season, more than once cut us off from supplies or facilities necessary for our work.

efforts has possibly limited somewhat the precision of the determinations.*

While I hope later to secure larger, and better, series of data on osmotic concentration in the tissue fluids of desert Loranthaceae, and to obtain series from mesophytic regions for comparison with those from the hygrophytic and xerophytic habitats now available, there is little prospect of the completion of this work in the near future. It seems proper, therefore, to place on record the results so far obtained on the desert species for the use of other physiologists.

In the present state of our knowledge, determinations of the properties of the tissue fluids of desert Loranthaceae have a two-fold interest.

1. In studies in the Arizona† and the Jamaican coastal deserts,‡ my associates and I have confirmed the conclusions of Drabble and Drabble and of Fitting by showing that the osmotic concentration of the sap of desert plants is in general far higher than that of those of mesophytic and hygrophytic regions. It seems a matter of considerable interest to determine whether the same relationship holds for the Loranthaceae of these climatically antithetical regions.

2. In our first study we found that the concentration of the tissue fluids of the parasite is generally, but not invariably, higher than that of the host plant. It seems desirable to test this

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* Because of the rapid evaporation in the desert air, the danger of differential water loss in the collection of the tissues of parasite and host was far greater in the desert series. Because of the higher temperature to which the tubes of tissue were necessarily subjected until they could be placed in the freezing mixture, the danger of changes in the composition of the sap were necessarily greater than in the cool climate of the Blue Mountains. The concentrations in molecules and ions of the solutes, not the nature of the constituent compounds which may possibly be somewhat altered, is the subject under investigation. It may be doubted whether standing even for a much longer time would seriously alter concentration. Furthermore, any changes of this kind would be quite as likely to affect the tissues of both host and parasite, and hence to leave the relationship between them unaltered, as to influence one alone.

† Harris, J. Arthur, & Lawrence, John V., with the coöperation of Gortner, R. A. The cryoscopic constants of expressed vegetable saps as related to local environmental conditions in the Arizona deserts. Phys. Res. **2**: 1–49. 1916.

‡ Harris, J. Arthur, & Lawrence, John V. Cryoscopic determinations on tissue fluids of plants of Jamaican coastal deserts. Bot. Gaz. **64**: 285–305. 1917.

conclusion against data from as widely dissimilar environmental conditions as possible.

II. PRESENTATION OF DATA

Since earlier studies have shown that in trees the concentration of leap sap is related to the height of insertion of the leaves,* care was taken in the collection of samples of the host leaves to secure them from as nearly as possible the same level as the parasite. Generally they were gathered from the same branch.

Osmotic concentration was measured by the cryoscopic method. Sap was extracted after freezing† the tissues to obviate the differential extraction of sap, first carefully investigated by Dixon and Atkins‡ and verified by ourselves.§

The results are expressed in terms of freezing-point lowering in degrees centigrade, corrected for undercooling‖ and in atmospheres pressure from a published table.¶

The actual constants for parasite and host, together with the habitats of the species and the dates of the determinations, are given below.

The original collection numbers are retained. The values at the extreme right are the constants for the parasites. Below these are given the differences between the concentrations of parasite and host, the positive sign indicating higher and the negative sign indicating lower osmotic concentration in the tissue fluid of the parasite.

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* Harris, J. Arthur, Gortner, R. A., & Lawrence, J. V. The relationship between the osmotic concentration of leaf sap and height of leaf insertion in trees. Bull. Torrey Club **44**: 267–286. 1917.

† Gortner, R. A., & Harris, J. Arthur. Notes on the technique of the determination of the depression of the freezing point. Plant World **17**: 49–53. 1914.

‡ Dixon, H. H., & Atkins, W. R. G. Osmotic pressures in plants. I. Methods of extracting sap from plant organs. Sci. Proc. Roy. Dublin Soc. N. S. **13**: 422–433. 1913. Also in Notes from Bot. Sch. Trin. Coll. Dublin **2**: 154–172. 1913.

§ Gortner, R. A., Lawrence, John V., & Harris, J. Arthur. The extraction of sap from plant tissues by pressure. Biochem. Bull. **5**: 139–142. *pl. 1.* 1916.

‖ Harris, J. Arthur, & Gortner, R. A. Note on the calculation of the osmotic pressure of expressed vegetable saps from the depression of the freezing point, with a table for the values of P for $\Delta = .001°$ to $\Delta = 2.999°$. Am. Jour. Bot. **1**: 75–78. 1914.

¶ Harris, J. Arthur. An extension to 5.99° of tables to determine the osmotic pressure of expressed vegetable saps from the depression of the freezing point. Am. Jour. Bot. **2**: 418–419. 1915.

In several cases more than one mistletoe was taken from the same host tree. In such cases determinations based on the sap of the individual parasites may be compared with a single constant for the host plant, or may be compared with the determination based on the sample of host leaves nearest the parasite. Differences which for some reason indicated by the context are regarded as of doubtful value are bracketed.

Phoradendron californicum Nutt.

Coll. 531, on *Acacia Greggii* Gray. Aug. 12.
$\Delta = 2.00$, $P = 24.0$
For host, $\Delta = 1.87$, $P = 22.5$ $+0.13$, $+1.5$

On sandy floor of Sabino Creek, near mouth of Sabino Canyon, Santa Catalina Mountains.

Coll. 546, on same species, Aug. 15. $\Delta = 1.82$, $P = 21.8$
For host, $\Delta = 1.68$, $P = 20.2$ $+0.14$, $+1.6$

Small arroyo on bajada between Tucson and Sabino Canyon, Santa Catalina Mountains.

Coll. 535, on *Cercidium Torreyanum* (S. Wats.) Sarg. Aug. 13.
$\Delta = 1.99$, $P = 23.9$
For host, $\Delta = 1.55$, $P = 18.7$ $+0.44$, $+5.2$
Coll. 574, on same species, Aug. 19. $\Delta = 2.45$, $P = 29.4$
No determination for host.

The first of these collections from *Cercidium* was taken in the same locality as the August 15 sample from *A. Greggii*. The second was taken from a very small shrub in Sabino Canyon, on a steep slope about two or three miles below Dam Site. The lack of daylight precluded a collection of the very small leaves of the host.

Coll. 267, on *Prosopis velutina* Wooton, July 6.
$\Delta = 2.65$, $P = 31.8$
For host, $\Delta = 2.64$, $P = 31.6$ $+0.01$, $+0.2$
Coll. 538, on same species, Aug. 14. $\Delta = 2.29$, $P = 27.5$
For host, $\Delta = 2.40$, $P = 28.8$ -0.11, -1.3

These two collections were from the same large mesquite tree, on the edge of a small arroyo on the upper bajada, near the mouth of Sabino Canyon. The first collection was taken before the earlier summer rains, the second after they had fallen. The samples of parasites were from different plants.

Phoradendron Coryae Trel., on *Quercus*

Dr. Trelease notes that certain of these numbers belong in his form *stenophylla*, but it has not seemed worth while for present purposes to separate these from the more typical *P. Coryae.*

As far as known this species occurs exclusively on *Quercus*. The leaves of these desert oaks are so hard that at the mid-summer season when these determinations were made it was impossible to express sufficient sap from them to make freezing-point determinations.

On *Quercus oblongifolia* Torr.
Coll. 282, Mistletoe 1, $\Delta = 2.23$, $P = 26.7$
Mistletoe 2, $\Delta = 2.09$, $P = 25.1$
Coll. 283, Mistletoe 1, $\Delta = 2.01$, $P = 24.2$
Mistletoe 2, $\Delta = 1.88$, $P = 22.6$

All four determinations were made on samples collected July 10 on two trees in the Basin, Santa Catalina Mountains.

Coll. 292, on *Quercus Emoryi* Torr. $\Delta = 2.15$, $P = 25.9$

The Basin, Santa Catalina Mountains, July 11.

Coll. 528, on *Quercus hypoleuca* Engelm. August 10.
$\Delta = 1.73$, $P = 20.8$

Coll. 570, August 19. $\Delta = 2.26$, $P = 27.1$

Both of these collections were taken from a very large *Phoradendron* on a small oak, growing among the boulders on the edge of Sabino Creek, in the Basin, Santa Catalina Mountains. The first determination seemed suspiciously low, and the second sample was taken from the same individual plant on the 19th to check the results.

Coll. 355, on *Quercus arizonica* Sarg. July 19.
$\Delta = 2.63$, $P = 31.5$

Near Mud Springs, Santa Catalina Mountains.

Coll. 356, on same species July 20. $\Delta = 2.43$, $P = 29.1$

On Mount Lemmon trail, between the Basin and Mud Springs.

Phoradendron macrophyllum (Engelm.) Cockerell on *Fraxinus attenuata* Jones

For the host and parasite I am able to give determinations made in the early spring of 1914 and in the summer of 1916. The results secured on the desert mistletoe in the early spring of

1914 suggested the desirability of the later studies in Jamaica and Arizona.

The spring determinations were made from trees in the sandy (generally dry) bed of Agua Verde Creek, Tanque Verde Mountains.

Coll. 94, Mar. 24, 1914. $\Delta = 2.56$, $P = 30.7$
For host, $\Delta = 1.39$, $P = 16.7$ $+ 1.17$, $+ 14.0$

The leaves of the host had not yet attained their full size. The leaves of the parasite, which was in flower, were of course old. A second visit to this locality was made later to determine whether the striking difference in the sap of the two sets of leaves might be due merely to differences in maturity. On April 8 the still not fully matured leaves of the host gave $\Delta = 1.44$, $P = 17.3$, agreeing well with the values obtained on our first visit.

Coll. 171, April 9, 1914. $\Delta = 2.28$, $P = 27.4$
For host, $\Delta = 1.63$, $P = 19.6$ $+ 0.65$, $+ 7.8$

These values, from a second large tree in the same locality, are in excellent agreement with those cited above.

The following determinations were made on samples collected along Sabino Creek, at the mouth of Sabino Canyon, Santa Catalina Mountains.

Coll. 268, July 7, 1916. $\Delta = 3.29$, $P = 39.5$
For host, $\Delta = 2.08$, $P = 24.9$ $+ 1.21$, $+ 14.6$
Coll. 270, July 7, 1916. $\Delta = 2.46$, $P = 29.5$
For host, $\Delta = 1.90$, $P = 22.8$ $+ 0.56$, $+ 6.7$

The first of these samples was taken from a single large mistletoe, the second from a number of small plants on another tree.

Coll. 576, August 19, 1916.
Sample B, $\Delta = 1.96$, $P = 23.6$
$- .29$, $- 3.4$
Sample C, $\Delta = 2.33$, $P = 28.0$
$+ 0.08$, $+ 1.0$
Sample D, $\Delta = 2.53$, $P = 30.4$
$+ 0.28$, $+ 3.4$
Sample E, $\Delta = 2.69$, $P = 32.3$
$+ .44$, $+ 5.3$

All these were taken from the same small host tree, with injured trunk and several dead limbs, but with the living parts apparently in a perfectly healthy and vigorous condition. The sap from the leaves of the host gave $\Delta = 2.25$, $P = 27.0$.

I was able to find only two trees of *Fraxinus* with *Phoradendron* in the Basin, Santa Catalina Mountains. The results are:

Coll. 518, Aug. 9. $\Delta = 1.97$, $P = 23.7$
For host, $\Delta = 1.58$, $P = 19.0$ $+ 0.39$, $+ 4.7$
Coll. 520, Aug. 9. $\Delta = 2.15$, $P = 25.8$
For host [$\Delta = 3.23$, $P = 38.7$] —— ——
For host, Aug. 19, $\Delta = 2.15$, $P = 25.9$
[± 0, $- 0.1$]

The two collections of the parasite made on August 9 are very consistent. The determination for the host in the case of the second is obviously erroneous, presumably because of contamination with salt. On August 19 another trip was made to the Basin for the specific purpose of obtaining another collection from this tree. The determination based on a sample of that date gives a distinctly lower value than the first determination from this tree, but a higher value than the one obtained August 9 from the first tree. Unfortunately there was not enough of the parasite for a second collection.

Phoradendron macrophyllum Jonesii Trel. on *Fraxinus attenuata* Jones

The following determinations were made from collections along Sabino Creek, at the mouth of Sabino Canyon, Santa Catalina Mountains.

Coll. 542, August 14, First Mistletoe $\Delta = 1.99$, $P = 23.9$
For host, $\Delta = 2.17$, $P = 26.1$ $- 0.18$, $- 2.2$
Second Mistletoe $\Delta = 1.94$, $P = 23.4$
Same host determination $- 0.23$, $- 2.7$

My notes state in regard to the first of these parasites that the leaves are very yellow. Note that in both cases the determination for the parasite is lower than is usually the case.

Coll. 575, August 19, 1916. $\Delta = 2.51$, $P = 30.1$
For host, $\Delta = 1.79$, $P = 21.5$ $+ .72$, $+ 8.6$
August 19, 1916. $\Delta = 2.54$, $P = 30.5$
Same host tree, $\Delta = 1.76$, $P = 21.1$ $+ 0.78$, $+ 9.4$

Two collections of leaves from the same host tree were made. The results are in excellent agreement.

Phoradendron macrophyllum on *Populus*

Four determinations on *Populus Wislizenii* (S. Wats.) Sarg. were secured from two large trees, 4–5 feet in diameter, on the banks of the Rio Rillito, August 12.

Coll. 532, Parasite 1, $\Delta = 1.96$, $P = 23.6$
$+ 0.35$, $+ 4.3$
Parasite 2, $\Delta = 1.91$, $P = 22.9$
$+ 0.30$, $+ 3.6$
For host, $\Delta = 1.61$, $P = 19.3$

The leaves of the host were taken as near as possible to Parasite 1.

Coll. 533, Parasite 1, $\Delta = 1.94$, $P = 23.3$
For host, $\Delta = 1.79$, $P = 21.5$ $+ 0.15$, $+ 1.8$
Parasite 2, $\Delta = 2.13$, $P = 25.6$
For host, $\Delta = 1.76$, $P = 21.2$ $+ 0.37$, $+ 4.4$

The two samples of the leaves of the host were taken as near as possible to the parasites with which they are compared.

III. DISCUSSION OF CONSTANTS

Taking the results for the broad-leaved *Phoradendron, P. macrophyllum* and *P. macrophyllum Jonesii*, on *Fraxinus*, the data show that in both of the two determinations made in the early spring the osmotic concentration of the tissue fluids of the parasite was considerably higher than that of its host plant.

The average of the two determinations is 29.05 atmospheres for the parasite as compared with 18.15 atmospheres for the host, or an average difference of 10.90 atmospheres.

In the summer collections, the data show that there are eight cases in which the osmotic concentration of the parasite is higher than that of the host as compared with three cases in which it is lower.*

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* The results for one determination (Coll. 520) are not included because the only trustworthy value for the host was obtained on a different date. Two of these determinations (Coll. 542) are based on two different parasites on the same tree, with only one determination of the best plant for comparison. In one case the leaves of the parasite were definitely noted as old. The third exception (Coll. 576) came in a series in which four samples were taken from a partly dead tree. Possibly this one of the four plants was not in a normal condition.

The average freezing-point lowering of the tissue fluids of the parasite is 2.383° as compared with 2.041° in the fluids of the host, or a difference of + .342°.

In terms of osmotic pressure, the average for the sap of the parasite is 28.63 atmospheres, that of the host is 24.50 atmospheres, and the average difference between them is + 4.13 atmospheres.

The four determinations of *P. macrophyllum* on *Populus* are consistent in indicating higher osmotic concentration in the parasite. The excess ranges, roughly, from 1 to 5 atmospheres. The average for the four comparisons is 23.85 atmospheres for the parasite and 20.33 atmospheres for the host, a difference of 3.52 atmospheres.

Thus there are for the leafy desert Loranthaceae 14 determinations in which the concentration of the parasite exceeds that of the host against three cases in which the reverse is true.

Of the five determinations based on *P. californicum* in which comparison with the host is possible, four show an excess for the parasite, but the difference is extremely slight in one case. Far more work must be done before any final conclusions can be drawn concerning the relationship of the sap concentration of parasite and host in the leafless forms.

IV. RECAPITULATION

This paper presents data toward the solution of the problem of the water relationships of the desert Loranthaceae.

Three species of the genus *Phoradendron*, the leafless *P. californicum* and the leafy *P. Coryae* and *P. macrophyllum*, have been investigated on a number of hosts.

The osmotic concentration of the tissue fluids of the Loranthaceae of the Arizona deserts is, roughly speaking, twice as great as demonstrated by similar methods in the tissue fluids of the species investigated in the montane rain-forest of the Jamaican Blue Mountains.

In desert Loranthaceae, as in those of the montane rain-forest, the osmotic concentration of the tissue fluids of the parasite is generally, but not invariably, higher than that of the host.

These studies will be continued.

INHERITANCE STUDIES IN PISUM. III. THE INHERITANCE OF HEIGHT IN PEAS*

By Orland E. White

Brooklyn Botanic Garden

As regards height, varieties of peas were classified by Mendel ('66) as either tall or dwarf. When these two types were crossed, the F_1 generation was either as tall or taller than the tall parent. The F_2 generation consisted of approximately 3 tall : 1 dwarf (actual proportions 787 tall : 277 dwarf, or 2.84 : 1). All of the dwarf plants and approximately one third of the tall (28 out of 100) bred true in F_3, while the remaining 72 F_2 talls gave both talls and dwarfs in the ratio of 3 : 1. These results were interpreted as demonstrating a one-factor difference between tall and dwarf varieties of peas.

However, Bateson ('05), Keeble and Pellew ('10), Lock ('05), and others found the inheritance of height in certain cases to be more complex than indicated by Mendel. A class more or less intermediate in height between dwarfs such as Nott's Excelsior and Little Marvel and such talls as Scotch Beauty, Champion of England, and Späte Gold was recognized, to which the name half-dwarf was applied. Such varieties as First of All, Velocity, and Express are excellent examples of this class. Bateson ('05) says half-dwarfs are easily distinguished from talls, and lays particular emphasis on the zigzag growth of the stem as a marked characteristic of this group. If all varieties ranging in height from 3.5 to 4 or 4.5 feet are to be regarded as half-dwarfs, the above statement regarding zigzag growth, in the writer's experience, is only true of one group of half-dwarfs and these have short internodes, as noted later. Evidently Bateson's half-dwarfs are

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* Brooklyn Botanic Garden Contributions No. 20. These studies on the genetics of *Pisum* are carried on in collaboration with the Office of Forage Crop Investigations and the Office of Horticultural and Pomological Investigations, U. S. Department of Agriculture. For other titles of this series, see "Literature Cited."

all of this type, but those of Keeble and Pellew ('10) and others belong to at least two types.

Crosses between talls and half-dwarfs gave all tall in F_1 and approximately 3 talls : 1 half-dwarf in F_2 in some cases (Tschermak, '02), while in other cases talls, half-dwarfs, and true dwarfs have appeared in F_2 (Bateson, '05, '09, p. 19). Half-dwarfs with long internodes crossed with half-dwarfs with short internodes gave talls with long internodes in F_1 and approximately 9 talls : 3 half-dwarfs (short internodes) : 3 half-dwarfs (long internodes) : 1 dwarf in F_2. The results actually obtained by Keeble and Pellew ('10) were 114 : 33 : 32 : 13—expected 108 : 36 : 36 : 12.

Notes taken by the writer for several years on the height, internode length, and internode number (per plant) of over 200 varieties of peas, grown under similar soil and climatic conditions, indicate a still greater complexity as regards the inheritance and classification of height in varieties of this genus.

For example, tall varieties (over 4.5 feet) may be divided into at least three distinct groups. One type of tall pea has 40 to 60 long internodes (Scotch Beauty, Späte Gold). Another type has 20 to 40 long internodes (Mammut, Goldkönig, White-Eyed Marrowfat). The internodes of each of these types average twice or more the length of the short internodes of the dwarfs. The third type of tall pea varieties is illustrated by Haage and Schmidt's "Graue Reisen Schnabel" which has 21 to 30 very long internodes. Variation in height and internode number among plants of the same true breeding variety is due largely to differences in environment. The absence of the factor for normal stem ($\underset{\smile}{Fa}$), causing fasciation, also brings about a shortening of the internodes. Other types of talls doubtless exist, but the writer's studies have not been detailed enough as yet to recognize them.

Crosses between the three types of talls, so far as they have been made, give in F_1 and F_2 all talls, but talls of different types. Large number of internodes is usually dominant over the low-number types. Sufficient data, as yet, are not available to determine the relation of these types in terms of factorial differences. Each type of tall undoubtedly represents a separate and distinct mutation.

As in the case of the tall-growing varieties of peas, the so-called "half-dwarfs" can be separated into at least two genetic types. One of these is illustrated by the examples of half-dwarf already mentioned—Velocity, First of All, and Express. These have long internodes, similar to the 40–60 and 20–40 long internode talls, but fewer in number, ranging between 10–20. The other type of half-dwarf has short internodes, similar to the short internodes of the true dwarfs. This type is illustrated by the variety Dwarf Gray Sugar, with internodes ranging in number from 20 to 40. The variety Autocrat, as studied by Keeble and Pellew (**'10**), probably also belongs in this category.

Half-dwarfs with long internodes crossed with short internode half-dwarfs give long internode talls in F_1 and long internode talls, long internode half-dwarfs, short internode half-dwarfs, and true dwarfs, approximating a 9 : 3 : 3 : 1 ratio in F_2. Similar results from such a cross, so far as the writer can judge, have been obtained by Keeble and Pellew (**'10**), although they have given them a somewhat different interpretation (see also Lock, **'05**). Half-dwarfs of each type crossed with similar half-dwarfs, as expected, breed true in F_1, F_2 and later generations. Half-dwarfs of the short internode type crossed with the 20–40 long internode tall type give in F_1 talls with long internodes, which in F_2 produce a population approximating 3 talls with long internodes : 1 half-dwarf with short internodes. The difference in height between such talls and such half-dwarfs is due largely to internode length, the number of internodes in each type being approximately the same. Half-dwarfs with long internodes crossed with talls with long internodes (20–40 type) give talls in F_1 and populations approximating 3 talls : 1 half-dwarf in F_2, both, of course, with long internodes, the difference between them in this case being due to internode number.

True dwarfs (6 inches to 3.5 feet high) in peas all have short internodes, ranging f om 8 to 20 in number. Laxtonian, Nott's Excelsior, and several French varieties obtained through the courtesy of Phillipe Vilmorin are excellent examples. When crossed with the various types of talls, the F_1 generation always consists of talls with long internodes, although large number of internodes may not be completely dominant over small number of internodes in certain cases, e. g., Pois nain à châssis, très hâtif crossed with Wachs Schwert (40–60 internodes tall). In such crosses, the F_1 generation is to be regarded as intermediate, so far as the gross character height is concerned, although this intermediate condition is brought about through incomplete dominance of high over low internode number. Tschermak ('01) also mentions obtaining intermediates in F_1, as regards height, from crosses of talls and dwarfs, though he says nothing about internode number or length. The F_2 generation from tall × dwarf or its reciprocal consists of four classes—talls with long internodes, half-dwarfs with either long or short internodes, and true dwarfs. These approximate a 9 : 3 : 3 : 1 ratio as in the case of short internode half-dwarf × long internode half-dwarf. Laxton ('06) obtained practically these same results. This is the cross usually

FIG. 1. F_2 generation tall and dwarf segregates from cross of tall × dwarf. Photo from cultures of E. M. East.

made to illustrate the inheritance of height and probably the one made by Mendel for the same object. What is usually meant by geneticists, so far as the writer can learn, when discussing inheritance of height in peas, is really the inheritance of difference in internode length. Hence all short internode varieties or segregates, irrespective of actual height or number of internodes, are classed as dwarfs, while all long internode varieties or segregates, irrespective of number of internodes, are classed as talls. Classified in such a manner, the F_2 population from such a cross as described above would have approximately 3 tall (long internodes) : 1 dwarf (all short internodes). The long internode half-dwarfs would be called talls, while the half-dwarfs with short internodes would be called dwarfs (see Bateson *et al.*, '05; Lock, '05, '08; Laxton, '06).

Crosses between half-dwarfs with long internodes and true dwarfs gave half-dwarfs in F_1 and approximately 3 half-dwarf (long internodes) : 1 dwarf (short internodes) in F_2 in the writer's experiments. Bateson ('05) commonly obtained intermediates in F_1 from crosses between half-dwarfs (presumably short internodes) and dwarfs.

The simplest interpretation of the above data involves the presence and absence of at least five genetic factors for height, two of which primarily determine the differences in internode length and three of which are largely responsible for the hereditary differences in number of internodes. These with their expression may be represented as follows:

Le = long internodes
Le_1 = very long internodes
T = 20–40 internodes
T_1 = 40–60 internodes
T_2 = 20–30 internodes

Absences

le = short internodes
t = 10–20 internodes

Le and T have been referred to in previous numbers of this series (White, '17 a and b), Le being the factor isolated by Mendel and confirmed by many later workers. T is referred to by Keeble and Pellew ('10) as the factor for robust stems, but in the writer's interpretation of their results, it determines the difference in internode number.

On the above interpretation, the factorial composition of the three classes of talls would be:

(1) $\underparen{\text{Le}}\text{T}$ = 20–40 long internodes.
(2) $\underparen{\text{Le}}\text{T}_1$ = 40–60 long internodes.
(3) $\underparen{\text{Le}_1}\text{T}_2$ = 20–30 very long internodes.

The factorial composition of the half-dwarfs would be:

(4) $\underparen{\text{Le}}\text{t}$ = 10–20 long internodes.
(5) $\underparen{\text{le}}\text{T}$ = 20–40 short internodes.

The true dwarfs on this scheme would represent the absences of $\underparen{\text{Le}}$ and T or (6) $\underparen{\text{le}}\text{t}$.

Sufficient data have not yet been accumulated to determine in any detail the relations of these factors to each other except in the case of $\underparen{\text{Le}}$ and T. Varieties with formula (1) crossed with (4) should and do give all long internode talls in F_1 and talls and half-dwarfs (long internode) in F_2. Combination (1) × (5) gives long internode talls in F_1 and approximately 3 talls (long internodes) : 1 half-dwarf (short internodes) in F_2. Combination (1) × (6) gives all long internode talls in F_1 and an F_2 population approximating 9 tall (l.i.) : 3 hd. (l.i.) : 3 hd. (s.i.) : 1 dwarf (s.i.). The two half-dwarf types, (4), (5) crossed with each other give all long internode talls in F_1, but an F_2 population similar to (1) × (6). Half-dwarf varieties (5) × dwarfs give intermediates in F_1 in some cases. The writer has no data on this cross as yet. Half-dwarf varieties with the formula $\underparen{\text{Le}}\text{t}$ (4) crossed with dwarfs (6) give all long internode half-dwarfs in F_1, and approximately 3 half-dwarfs : 1 dwarf in F_2.

Critics of Mendelian methods and conceptions will say again, as the above results are noted, "another unit-character has been split up." But the writer wishes to emphasize that with the same genetic pea material that Mendel and others have used to obtain the F_2 ratio of 3 talls : 1 dwarf, the same results will still be secured. The difference in interpretation has come from more detailed studies and the inheritance of height in peas has become complex only because of studies on new or distinctly different material, the characters of which, there is reason to believe, are due to distinct mutations.

A large series of crosses involving height is in progress, and the data from these will be published in detail.

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CENTROSOMES DURING EARLY FERTILIZATION STAGES IN PREISSIA QUADRATA

By Margaret Graham

Hunter College

(WITH PLATE 8)

The problem as to the behavior of the centrosome during cell and nuclear fusion cannot be said to be settled for either plant or animal cells and from this standpoint I am engaged in an investigation of the processes connected with fertilization in *Preissia quadrata* (Scop.) Nees.

My material was collected from gorges around Ithaca and prepared for sectioning at Cornell University. I am indebted to Professor G. F. Atkinson for the privileges of the botanical laboratory there, where for several years I experimented with methods of handling the plants and with various killing reagents. I also acknowledge the privileges of the laboratory in the Cornell Medical College at Ithaca. The material was killed in the field in a modified Flemming solution. The sections were stained and studied at the botanical laboratory at Columbia University and were examined by Professor R. A. Harper, to whom I am indebted for a critical examination of my stained preparations.

Dr. Osvaldo Kruch ('90) observed many eggs of *Riella Clausonis* with one antherozoid in the cytoplasm. He also observed that both nuclei before fusion were approximately of the same size. Fusion of the pronuclei was not observed, nor were astral rays and centrosomes. Since this article by Kruch no other has appeared on fertilization in the liverworts.

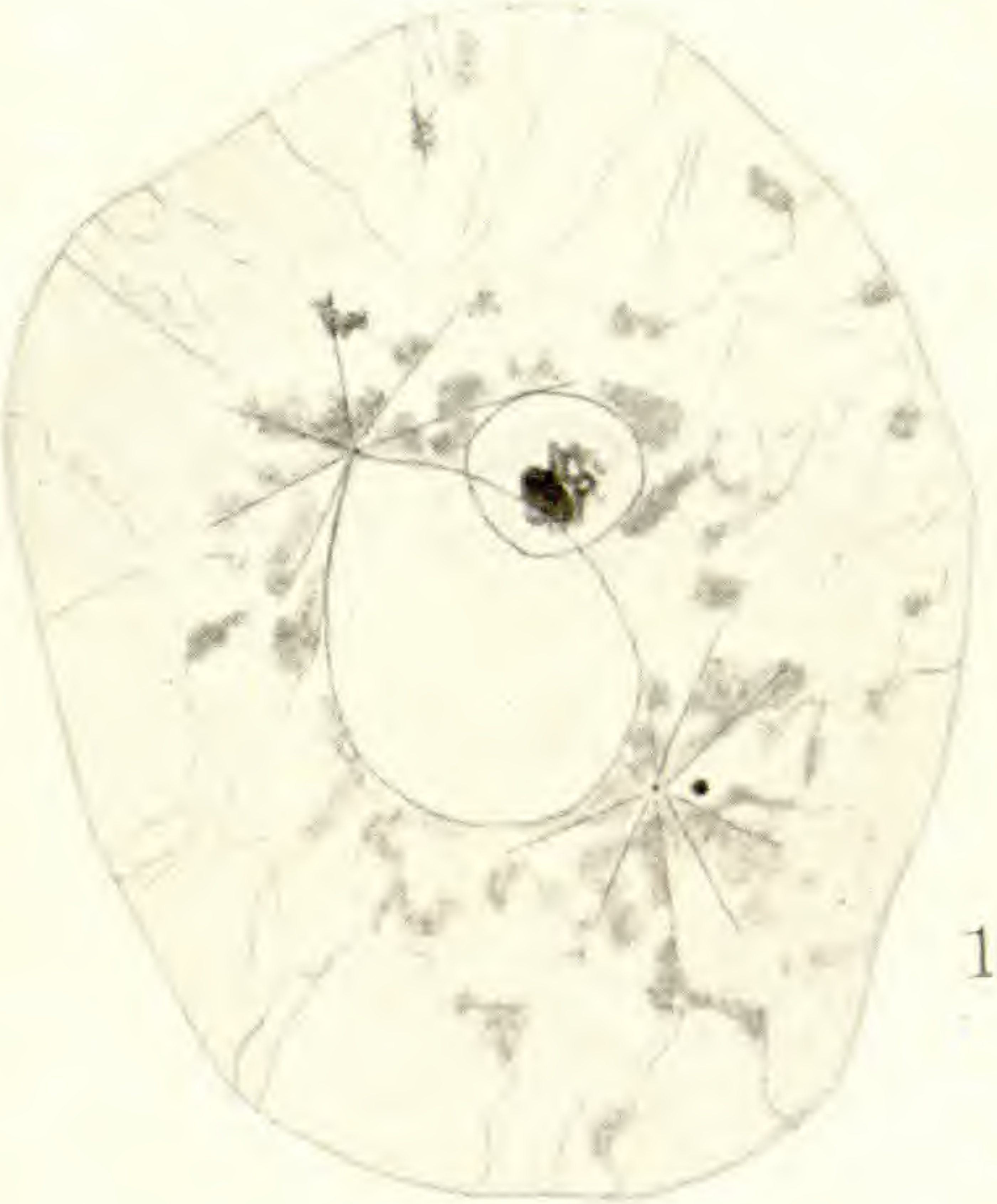
I shall describe here only the stages after the egg has been penetrated by the antherozoid and when the pronuclei are already near together. During this stage the cytoplasm of the egg of *Preissia quadrata* is plainly made up of two zones. The inner zone is granular with rounded bodies forming a dense aggregate that lies in masses around the pronuclei and among the rays of the centrospheres. A small amount of the same material also clings to the cytoplasmic fibers at the periphery of the cell. This dense cytoplasm may appear more or less alveolar at this stage. Prior to fertilization the whole cytoplasm of the egg has this consistency. The outer zone of the cytoplasm is coarsely vacuolar. The films between the vacuoles are very thin and delicate. A few larger and quite dense homogeneous granules are scattered through both zones of the cytoplasm. The egg nucleus and the nucleus of the antherozoid are plainly differentiated by their size and in FIGURES 1, 2, and 3 are shown lying in the central part of the cell. In FIGURES 1 and 3 their nuclear membranes are in contact.

In the dense cytoplasm at the opposite poles of the egg nucleus astral rays are seen converging upon small dense rounded bodies, the centrosomes (FIGS. 1 and 2). These rays extend long distances through the cytoplasmic ground substance. They may pass close to the nuclear membrane or may touch it. A fiber radiating from the centrosome at the upper part of FIGURE 1 touches the nuclear membrane of the antherozoid; another radiating from the same centrosome touches the outer membrane of the egg nucleus. The astral rays make up an open aster with few rays; but they are very definite fibers easily distinguishable from other cytoplasmic structures. Peripherally they end rather abruptly and have no conspicuous physical connection with any of the other elements of the dense cytoplasm. It is quite possible that there are other shorter and more delicate rays, but I have drawn only those which are plainly differentiated. All these fibers center on a centrosome which seems to be a single body.

FIGURE 3 shows a slightly earlier stage of fertilization. A centrosphere lies above the egg nucleus, the rays extending to its membrane. FIGURE 4 is another section of the same egg and shows a second centrosphere.

One or more large dense bodies lie among the astral rays a short distance from the center, but they do not constitute a part of the region on which the rays center (FIGURES 1–4).

Centrosomes and asters have been demonstrated in the vegetative cells of liverworts by Farmer and Reeves ('94) in the germinating spore of *Pellia epiphylla* and by Van Hook ('00) in the cells of the stalk of the archegoniophore of *Marchantia polymorpha*.



1

2

3

4

GRAHAM: CENTROSOMES IN PREISSIA

Centrosomes have been observed in the divisions just preceding spermatogenesis and as blepharoplasts, during the metamorphosis of the antherozoid mother cell. From my studies it is evident that they are also present in the fertilized egg at the time when the pronuclei are paired.

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EXPLANATION OF PLATE 8

The figures were drawn with the aid of a Bausch & Lomb camera-lucida, the drawing being at the level of the base of the miscrocope; Zeiss 1.8 mm. oil-immersion objective, 1.25 N. A., and oc. 4. Magnification about 1431 diameters.

Figures 1 and 2 are sketches of drawings made for another article.

FIG. 1. A section of the egg cell. The membranes of the egg and antherozoid nuclei are in contact. Centrospheres lie at the poles of the egg nucleus.

FIG. 2. A section of the egg cell in which the nucleus of the antherozoid lies in the cytoplasm near the egg nucleus. A centrosphere appears at the poles of the egg nucleus.

FIG. 3. A slightly younger stage of fertilization. One centrosphere is shown above the egg nucleus.

FIG. 4. Polar view of a centrosphere lying in the cytoplasm of another section of the egg shown in figure 3.

ORIGIN AND DEVELOPMENT OF THE LAMELLAE IN SCHIZOPHYLLUM COMMUNE

By J. F. Adams

Columbia University

(WITH PLATE 9)

Fries ('15) in establishing the genus *Schizophyllus* which he later ('21) changed to *Schizophyllum* says that it is to be distinguished from *Agaricus* and *Merulius* by the longitudinal splitting of the gills with the resulting halves becoming revolute.

Hoffman ('60) describes the carpophores as consisting of lamellar systems which correspond to the crenatures of Buller ('09). The smaller secondary gills are often but not always divided. He believes that the upper surface of the carpophores should be regarded as a "pellicula" comparable to the velum.

Winter ('84) and de Bary ('87) add nothing of consequence to the description by Hoffman.

Fayod ('89) includes *Schizophyllum* in the tribe "Panoides" with *Panus* as representative of the gymnocarpus type. He noted that the young lamellae are entire and held that the splitting was hygroscopic.

Buller ('09) is quite explicit as to the origin of the gills. He says in substance:

"The under layer of the pileus is produced downwards to form the gills. Whilst a pileus is extending by marginal growth, the interlamellar spaces gradually widen. When a space has attained a certain width, it becomes divided into two down the middle, owing to the formation within it of a new gill which arises as a short median downgrowth from the pileus flesh. The splitting of the gills permits the hymenial surfaces being protected during periods of drought. The recurving of the gill plates may be partly explained when a fruit body dries up by the cell walls of the hymenial and sub-hymenial layers contracting much more strongly in the vertical direction than those of the tramal layer."

There is no clear account of the early stages of gill formation in the literature and I have undertaken to fill this gap by the present study. The nature of the whole carpophore also becomes much clearer with a knowledge of the method of origin of the gill.

MATERIALS

Carpophores of *Schizophyllum commune* for this study were collected in the field and also grown on agar. Lima-bean agar, prune agar, and dung agar were favorable media. The cultures were grown in flasks of 50 c.c. and 250 c.c. capacity. Cultures were started from immature carpophores collected in the field, which were washed in distilled water before being transferred to the flask.

Within five days after the carpophores are planted on it the agar surface is covered with a dense white growth of mycelia. The hyphae in cultures are conspicuously branched and microscopical examination shows numerous clamp connections. The hyphae average 3 μ in diameter.

Dense aggregations of buttons often develop over the agar surface. From the cut end of the carpophores and from their margins small buttons are first formed. A number of the buttons when they are in dense clusters fail to mature. Numerous abnormal forms appear, as has been reported also by Miss Wakefield ('09). In some cases an immature carpophore that is transferred to agar will continue its normal development by marginal growth and form a large normal fruit-body (PL. 1, FIG. 1).

Various stages in the development of the carpophore were fixed for study in Flemming's medium mixture, dehydrated, and embedded in 52 paraffin. Sections were cut from 6 μ to 12 μ in thickness.

THE YOUNG CARPOPHORE

The young button appears as a dense, globular mass of intertwined hyphae raised above the substratum. As noted, they often appear in clusters. These carpophore primordia later become differentiated into cylindrical outgrowths which enlarge radially at their outer end. They vary in length from about 1 to 10 mm. and up to 5 mm. in width at the tip.

They are clothed with a loose outgrowth of hyphae from their earliest appearance. These hyphae are thick-walled and no branching was observed. Clamp connections or cross-walls were not found in these superficial hyphae.

Transverse vertical sections of young buttons show a dense homogeneous mass of intertwined hyphae developing parallel with the elongating axis of the primordium. The hyphae show conspicuous clamp connections. The carpophore primordia are of leathery consistency and show no evident differentiation until the appearance of the hymenium primordium.

THE HYMENIUM

In young buttons the first appearance of the fruiting layer is just below the upper end. It consists of a growth of densely staining hyphae. Horizontal sections show this first structure or plectenchyma of hyphae centrally located. With further growth of the carpophore primordia they become somewhat elliptical in outline. The individual hyphae now become oriented, their free ends converging towards the center of the mass.

The first gill cavity is formed in this hymenium primordium. The oldest primordia are in the central part and the youngest towards the sides, showing the order of their formation (TEXT-FIG. A, NO. 2).

The whole carpophore enlarges and as result of growth tensions the gill cavities appear in the center of these primordia of the hymenium. The gill cavities are lined from the first by a palisade layer. The palisade layer is increased by the intercalary addition of new elements with the further increase in size of the gill cavity. The elongated cells composing the palisade layer stain deeply and appear to arise as a system of short branches from the subjacent hyphae which are to form the trama.

The gill cavities thus represent from the first the space between the adjacent halves of two lamellae. The hymenia are oldest toward the base and less undifferentiated toward the tip of the carpophore.

In two instances gill cavities were observed developing in the trama of the matured lamellae. It was observed several times that the inner surface of the gill cavity before maturity was not completely covered by the palisade layer. This condition is found usually along the lower edge of the gill cavity, but the condition becomes normal with the maturity of the gill cavity (PL. I, FIG. 4). The wall between two adjacent gill cavities is occasionally quite weakly developed owing to the close proximity in their origin.

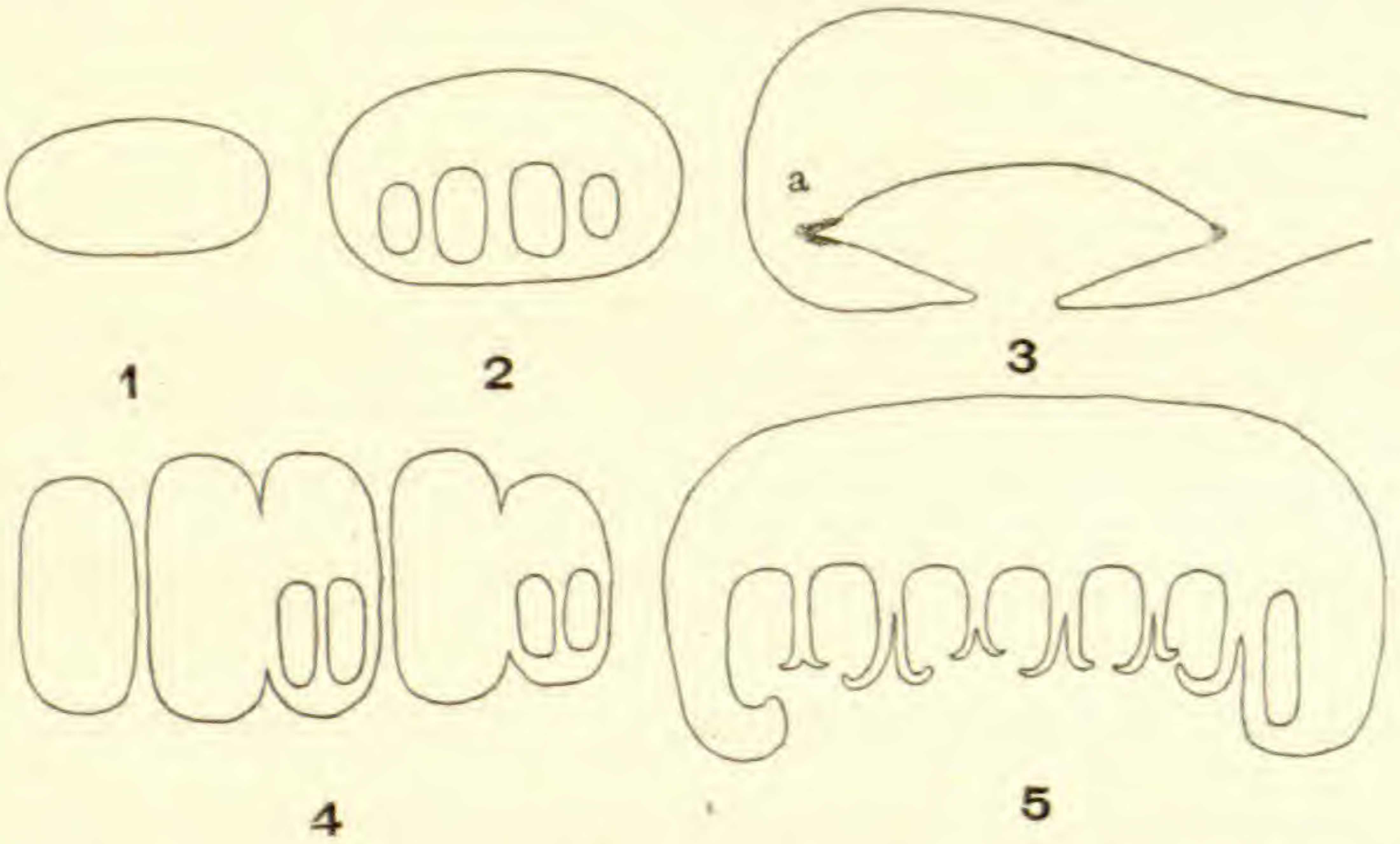

FIG. A. Diagrams of sections illustrating different stages of development of the early carpophore. 1. Transverse vertical section of a button in which no differentiation has appeared. 2. Section cut as above showing later stage with four endogenous and separate gill cavities, the lateral ones younger. 3. A longitudinal median section through a young carpophore showing one of several gill cavities which have opened longitudinally below. *a*, Region of extension of the hymenium primordium. 4. Transverse vertical sections through the apical growing region of the carpophore, showing the origin of the crenatures, two of which are already separated by clefts extending to the dorsal surface of the carpophore. The middle and outer crenatures at right show gill cavities comparable to those in Fig. 4, Pl. 1. In the case of the others, similar gill cavities appear in sections nearer the base of the pileus. 5. Transverse vertical section like those of Buller through the median portions of a carpophore, showing a series of young lamellae, the gill cavities open below except in the case of the one at the right. The gills already show more or less of the characteristic splitting.

In such instances the separating wall, which would normally become a lamella, gradually thins out and disappears. Instead of two gill cavities normally maturing they become one by the abortion of the separating wall.

THE LAMELLAE

The gill cavities split along their lower edge and lamellae are thus completed. They consist, as noted, of the adjacent walls of two gill cavities which originate endogenously as tubes in the substance of the carpophore.

The tissue above the gill cavities already formed increases by intercalary growth and in general the gill cavities lie much nearer the ventral than the dorsal surface of the carpophore. The tissue below the gill cavity appears gradually to become looser in texture as the gill cavity gets larger and this favors the splitting by which the edges of the gills are set free.

Owing to the method of their origin the margins of the lamellae are never entire, but appear irregular and frayed out. The final splitting of the lamella is apparently a hygroscopic phenomenon as described by Buller ('09). The trama is continuous with the tissue of the pileus above the gill. In transverse sections of the lamellae the split is seen to be parallel with the elongated hyphae of the trama, as seen in PLATE I, FIGURE 7.

FURTHER DEVELOPMENT OF THE CARPOPHORE

The growth of the carpophore is marginal and the lamellae are extended in length by the elongation of the gill cavities and the palisade layer in the interior *pari passu* with the development of the carpophore.

In the young immature carpophores after several lamellae have been formed the margin becomes divided into the crenatures. These crenatures are due to the development of a cleavage lamella splitting in certain cases clear through the dorsal surface of a pileus (TEXT-FIG. A, NO. 4). They not only include the primary gills but allow for the origin of new gills on either side in the usual way. The later-formed lamellae are narrower and thus we get the lamellar systems of Fries and the fasciculi of gills of Buller. The pileus enlarges by the continued growth of the primary lamellae and the successive development of additional lamellae, all of which have their origin from gill cavities in the manner described. The more central crenatures are the oldest and the younger are towards the sides of the pileus.

In mature carpophores it is often observed that a short gill appears isolated between the right and left halves of the adjacent lamellae (TEXT-FIG. B, *c*). At the point where such a lamella originated the crenature was increasing in width. The new lamella was continued from its point of origin so long as the growth of the crenature allowed for its development. After attaining a certain width the crenatures gradually become narrower and thin out at the margin. Under such conditions of limited growth some of the enclosed lamellae in the crenature can no longer be continued and do not reach the margin of the crenature. In the mature carpophore the margin is always thinned out and the gills thus become lanceolate in form.

DISCUSSION

In recent years considerable advances have been made in our knowledge as to the origin and development of the lamellae in different members of the Agaricaceae. The endogenous origin of the lamellae has been firmly established for a number of forms.

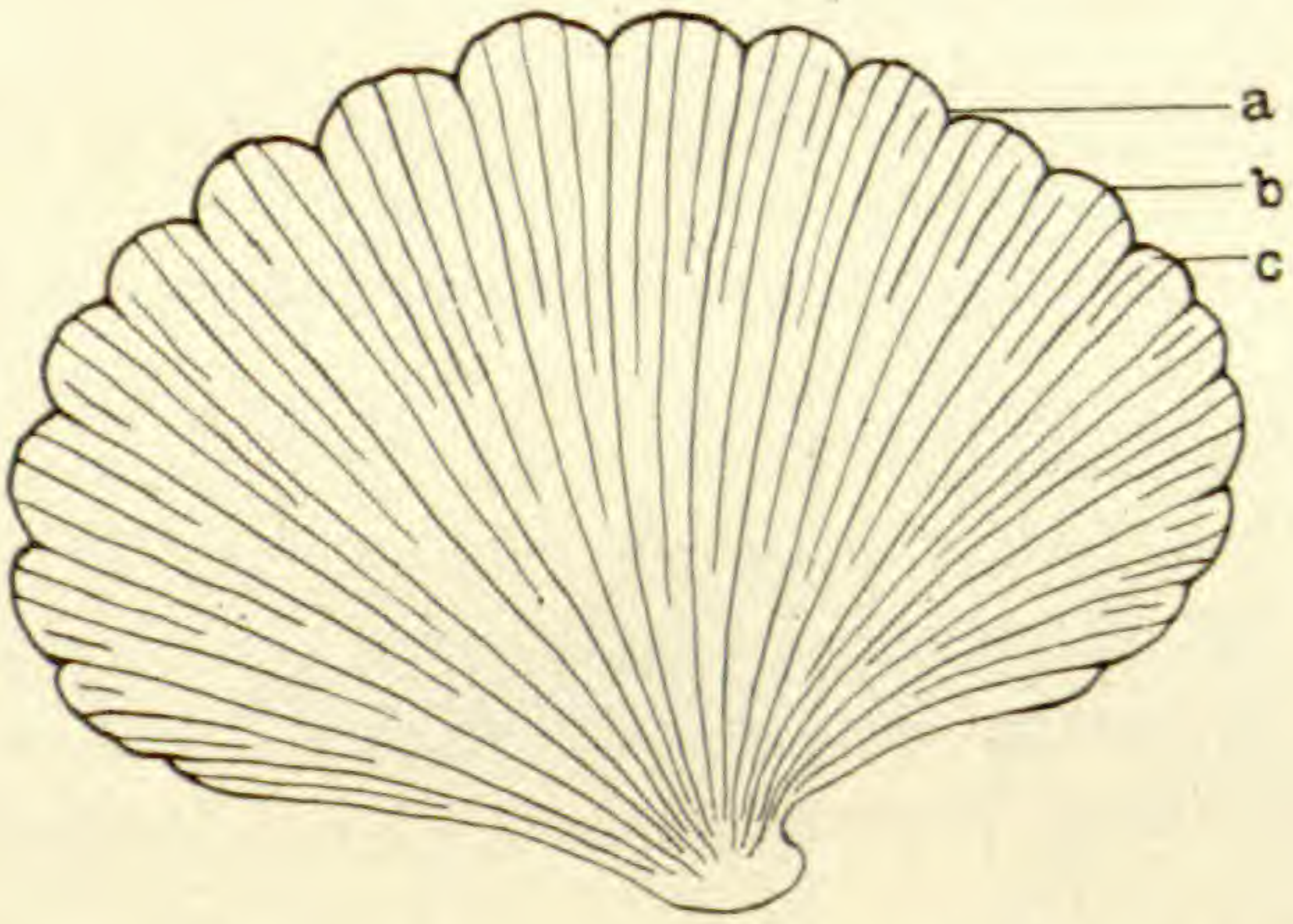

FIG B. Diagram of ventral surface of carpophore showing arrangement of crenatures and gills. *a*, primary gill; *b*, secondary gill; *c*, a disconnected secondary gill.

In *Schizophyllum* the lamellae originate by the formation of endogeneous gill cavities in a fashion similar in principle to that which Levine ('14) finds in *Coprinus micaceus*. They are developed simultaneously in *C. micaceus*, while in *Schizophyllum* they are successively formed. In both cases a series of gill cavities are produced which represent the space between the adjacent sides of a pair of lamellae. There is no general gill cavity into which the lamellae grow downward. In *Schizophyllum*, owing to its habit of growth, this method of origin of the gill cavities as independent tubes is diagrammatic in its simplicity and whether *Schizophyllum* is a progressive or a reduced type we have in it the evidence that gills in their essential nature are hymenium-bearing plates between independently originating endogenous gill cavities.

To Professor R. A. Harper and Dr. M. Levine I wish to express my sincere appreciation of their kindly criticisms and helpful suggestions.

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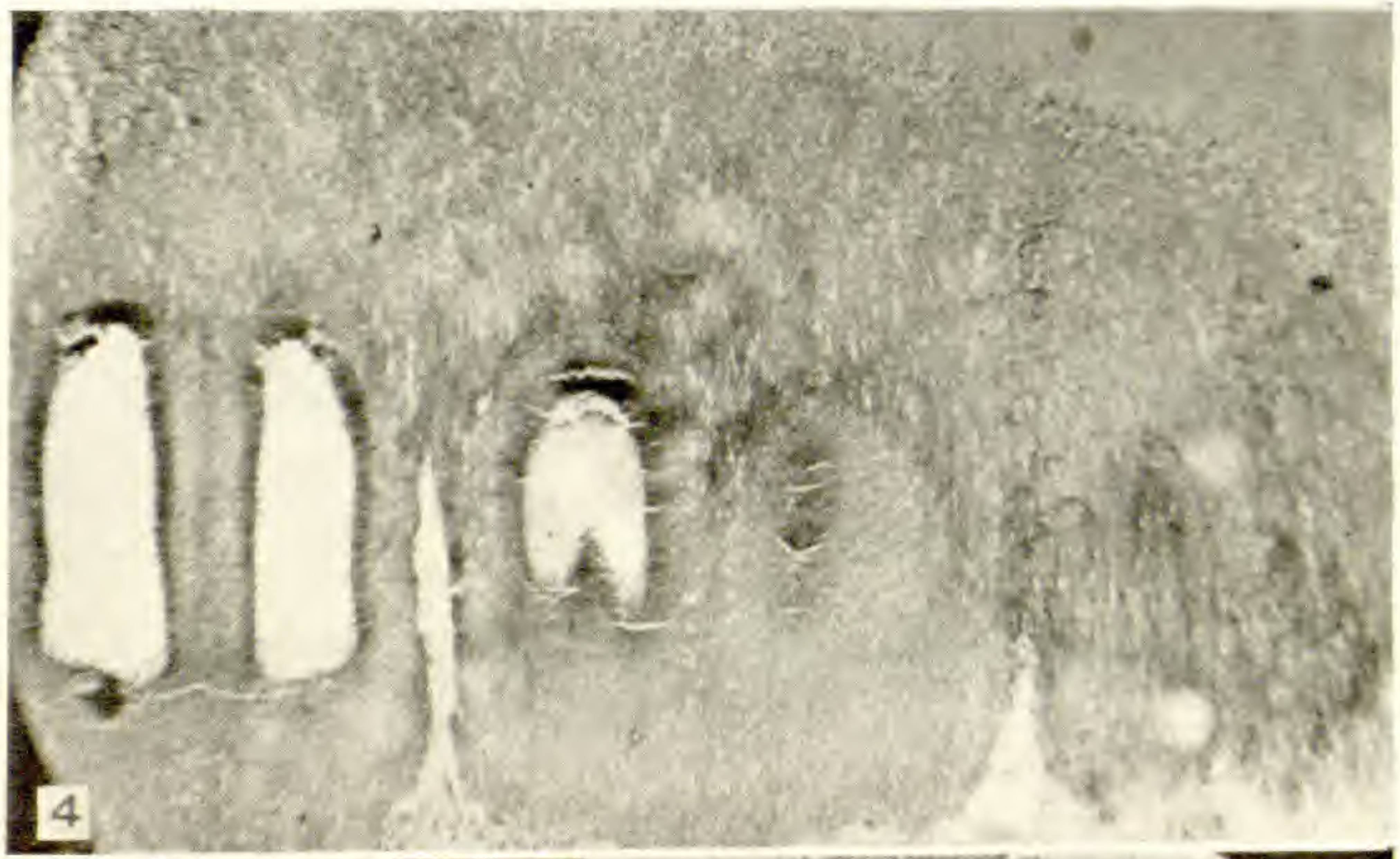
EXPLANATION OF PLATE 9

FIG. 1. A carpophore thirty-four days old, grown from a piece of *Schizophyllum commune* transferred from a branch of birch. 6/13 of the natural size.

FIGS. 2 and 3. Transverse vertical sections through three crenatures of a carpophore with gill cavities in different stages of development. Fig. 3 is further back from growing region than Fig. 2. The gill cavities are seen to lie nearer the ventral than dorsal surface. Photomicrograph × 26.

FIG. 4. Transverse vertical section through the growing region of a carpophore, showing only three crenatures as indicated by the two ventral furrows. The first crenature to the right shows undifferentiated tissues. In the middle crenature appears an imperfectly developed gill cavity and a closed hymenium primordium in which a gill cavity will appear. The crenature on the left shows two mature gill cavities. Photomicrograph × 43.

FIGS. 5 and 6. Sections cut as above, slightly oblique through young carpophore in which gill cavities are open, showing three gills that have split along their lower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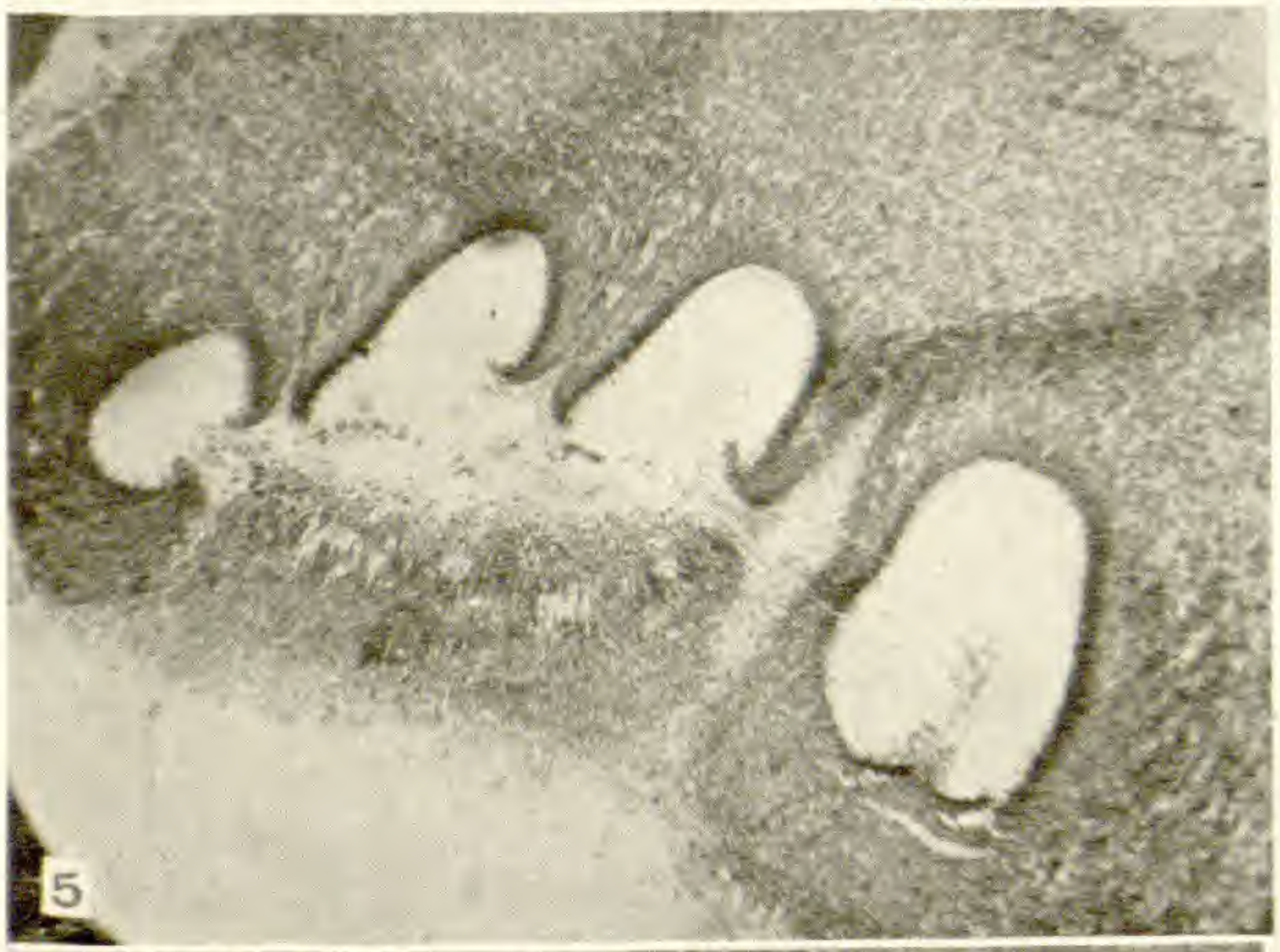
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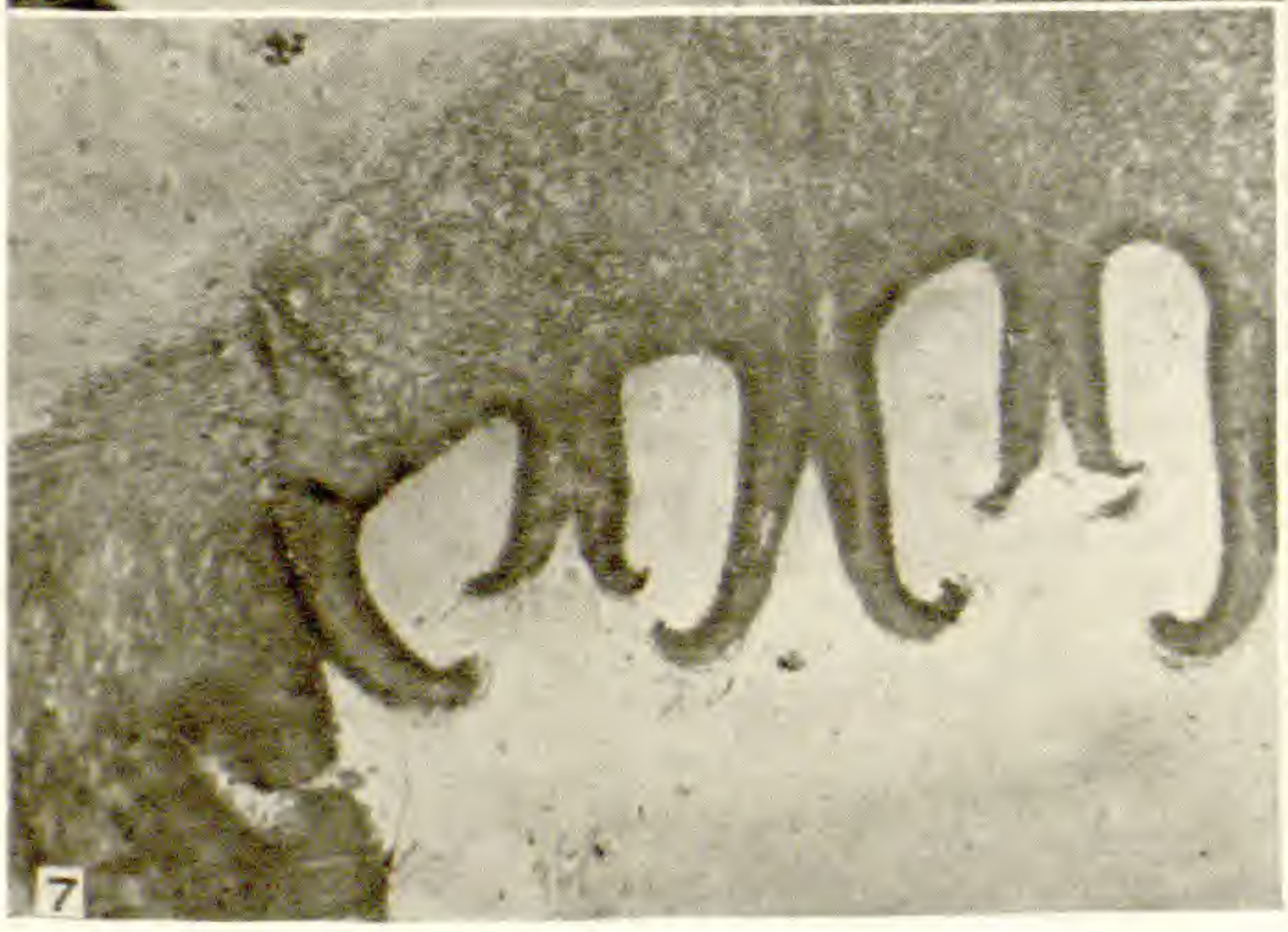
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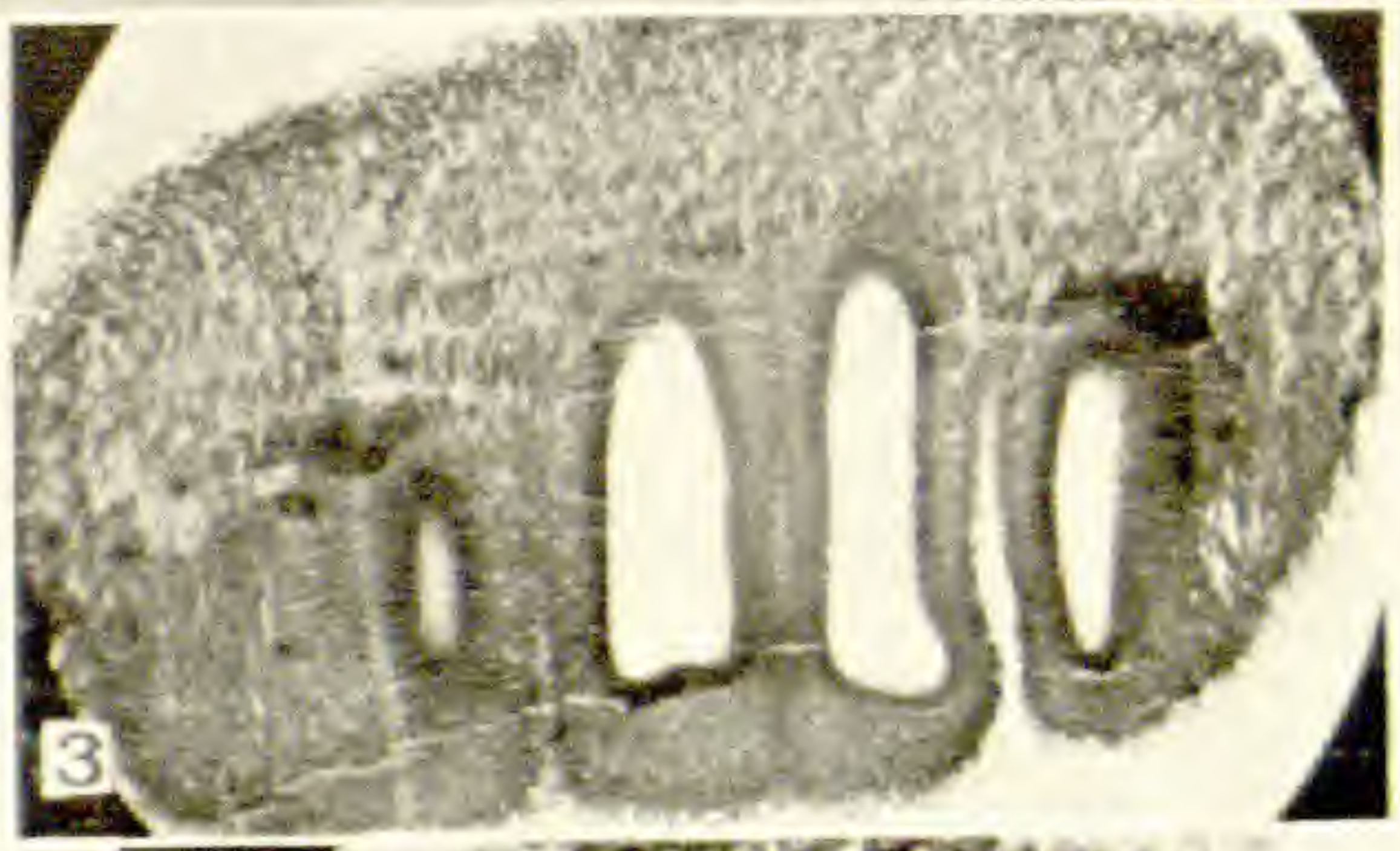
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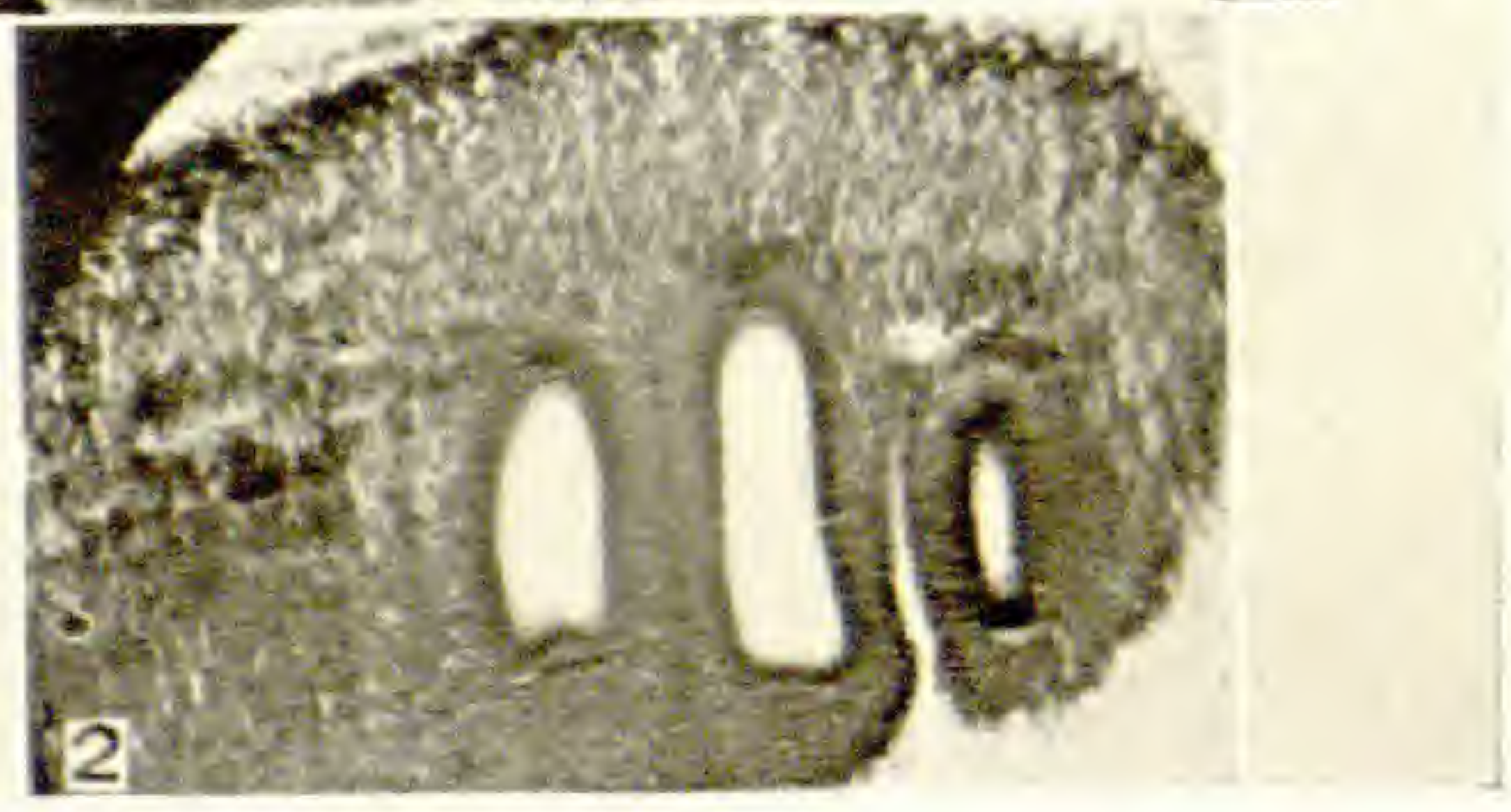
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SCHIZOPHYLLUM COMMUNE FR.

edge. The irregular and frayed out margins of the lamellae are already evident. Fig. 6 is further back from the growing region than Fig. 5 and a small closed hymenium primordium appears in the lower lateral margin to the right. Photomicrographs. Fig. 5 × 35; Fig. 6 × 26.

FIG. 7. Section cut as above through the median portion of a carpophore showing a series of lamellae. The gill cavities are opened, forming the lamellae which are here seen split. Photomicrograph × 38.

STATISTICAL STUDIES OF FLOWER NUMBER PER HEAD IN CICHORIUM INTYBUS: KINDS OF VARIABILITY, HEREDITY, AND EFFECTS OF SELECTION

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The New York Botanical Garden

(with plates 10–13)

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INTRODUCTION

Much study and speculation have been directed to the so-called fluctuating variations in the effort to determine their significance in development, in heredity, and in evolution. One of the principal reasons why such investigations have not been more conclusive undoubtedly rests in the difficulty of properly grading each of the individuals that comprise the species, the population, the generations, or the lines of descent to be analyzed.

This difficulty is frequently present in the more readily measurable or quantitative characters, especially when the estimate of the individual involves measurements of homologous organs among which there is also fluctuating variability. There are in such cases two grades of fluctuating variability: one is an individual variability (using this term as defined by de Vries, '01, p. 37, to refer to differences between individuals as such), the other is a partial variability (de Vries, '01, p. 37) which is a variability within the individual. The latter exists within the former and when present the estimate of the individual and of individual variability involves partial variability and is only adequate to the degree that the determination of partial variability is adequate.

It will also readily be recognized that partial variability may be complicated further by the development of homologous organs or parts of the organs at different times: the variations may involve organs which mature over a somewhat extended period either in different years or in a single season. A marked example of the latter is to be seen in perennials which produce a new crop of leaves, flowers, and fruit in consecutive years, giving inter-year variations which may involve the age of the individual. Furthermore, annuals, biennials, and perennials most frequently show a more or less extended period of development in a single season, during which homologous organs come into maturity with quite different positions on a plant and at quite different times.

All these aspects or factors of partial variability complicate the adequate determination of the expression of the capacities of an organism, and, it would seem, are factors that must be considered in an analysis of individual variability upon which any discussion of variation, heredity, or selection is based.

Furthermore, partial variability (as well as individual variability) may involve different kinds or grades of characters such as: (1) size, as of seeds, fruit, etc.; (2) chemical properties, as color, sugar-content, etc.; (3) number of homologous organs grouped together in a specialized structure such as the number of flowers in an inflorescence or the number of petals or sepals in a flower. Bateson has used the term "meristic" to apply to variation in number, as distinguished from substantive (such as color) variations which are more qualitative. The term "meristic" is, however, not applied solely to partial variability.

Further, partial variability may involve elements of differentiation which may not be suspected from random observations and collections of data, but which may constitute a source of error. The relation of fluctuating variability to differentiation is by no means clear, as the discussions of Pearson ('01 and '02a) and Bateson ('03) indicate. Very generally, however, the element of differentiation has been entirely disregarded in statistical studies of characters exhibiting wide partial variability.

The development of varying numbers of flowers in the different heads produced on a plant of a species of Compositae illustrates a type of partial meristic variation in the total number of flowers per head. If there be a noted differentiation among the flowers in a head, the number of both ray- or disk-flowers may vary. The compact inflorescence terminating a branch is itself considered as a unit structure in the study of partial variability upon which the value of the individual is to be based. The study of flower number in the Compositae, particularly the variation in the number of ray-flowers, has received much attention. The biometrical treatment inaugurated by Quetelet and Galton has been utilized in the descriptions and analyses of the performance of a species as a whole and of various populations and lines within a species. These studies have not always recognized the extent and kinds of individual and partial variability that may exist, or the degree to which differentiation may be recognized as operative in what appear as chance variations. The reasons for this will be obvious from the following considerations of the points of view and aims which influenced and guided different investigators in their studies.

REVIEW OF LITERATURE PERTAINING TO NUMBER OF FLOWERS PER HEAD IN THE COMPOSITAE

I. LUDWIG'S EVIDENCE THAT FLOWER NUMBER IS A SPECIFIC CHARACTER

Ludwig was one of the first to investigate intensively botanical subjects by biometric methods and his studies were especially directed to problems relating to number of flowers per head in various Compositae. He also investigated species of Umbelliferae as to the number of rays per umbel. His interest at first centered on the analysis in Galtonian terms of flower number *for species as such.* In the Compositae he studied those species which have both ray- and disk-flowers, but confined his observations almost exclusively to ray-flowers.

Ludwig did not realize the importance of the behavior of the individual plant, hence his method involved counts of heads collected indiscriminately. From such data curves were constructed to determine the behavior of the particular species, and especially to determine the highest mode or the maximum frequency of number per head. In the collection of data therefore, for the most part, no special recognition was given to individual variability and, of course, partial variability was ignored.

Ludwig ('95) published a summary of all his studies, which involve twenty-six genera and over sixty species of Compositae. The maxima determined for the number of ray-flowers per head are given for the different species. Often the counts were made from only a few flower heads so that the maximum is frequently not to be considered as established, as Ludwig himself fully recognized.

The largest number of counts made of any composite was of *Chrysanthemum Leucanthemum*. Data for 17,000 heads were collected in Europe at different places and at different times of the year over a period of several years. Ludwig concludes that 21 ray-flowers per head is the number characteristic of this species. In no instance does he give data showing that a race with a different maximum was found growing in isolation, but he considered that such races were indicated by secondary maxima obtained from data of mixed populations.

Data for ray-flower number of approximately 12,000 heads of *Bellis perennis* (Ludwig, '98) were presented to show that maxima may occur on the "Nebenzahlen" of the Fibonacci series, i. e., 39, 42, 55, 63, which were considered as "duplica" or "triplica" of various numbers of the main series. The only maxima that can be considered as at all established for *Bellis perennis* are 34 (one of the main series) and 42 (twice 21). Study was also made of total flower-number per head in *B. perennis*: 860 heads were counted and for these the range was from 63 to 233, a very large range of variability.

For *Chrysanthemum inodorum* (Ludwig, '95), data for 1,000 heads reveal a range in ray-flower number from 10 to 32 and a pronounced maximum at 21.

The data for *Chrysanthemum segetum* (Ludwig, '04) are of special interest as this is the species in which de Vries later made selection experiments. Ludwig reports 750 counts made in one locality and 250 made in another. Of the 750 from the one locality, 150 were made on July 29 and 600 on August 30. The 250 counts in the other locality were made on August 16. This is the only instance where Ludwig reports the dates of collections. However, the two series show no significant differences either in maxima or in range of variability; for the 750 counts the maximum is at 13 and the range from 11 to 23; for the 250 counts the maximum is 13 and the range from 10 to 23. Ludwig thus failed to find any evidence that here differences in flower number may appear according to age of a plant or to different stages in the period of bloom, such as will be reported in this paper for *Cichorium.*

For *Anthemis arvensis* Ludwig ('95) reports that for 1,802 flower heads the number of ray-flowers ranged from 2 to 21 with a maximum at 8 and some indications of a secondary one at 12–13.

In only two cases did Ludwig ('87) make a study of individual plants. In *Achillea Ptarmica* the modes for number of ray-flowers were determined for each of 79 plants; 30 plants gave a mode at 8; for 17 the mode was at 13; and for the other 32 the modes were about evenly distributed at numbers ranging from 9 to 12 inclusive. The total number of flower heads counted was 1,048 and the number of ray-flowers ranged from 6 to 15, with a maximum at 8. For *Senecio Jacobaea* the distribution of ray-flower number for 5 individual plants was studied. The range here was small, being from 12 to 14 and the total number of heads counted was 109.

In only a few cases does Ludwig consider the number of all the flowers produced per head. Such a study for *Bellis perennis* has been noted above. For *Senecio nemorensis* he presents ('96) data for 500 heads, which show that the total flower number per head ranged from 15 to 26 with maxima at 18 and 21, and the maximum for the ray-flowers in 357 heads of these was 5, with a very small variability. In these studies, however, the behavior of individual plants was not considered. Studies of total flower number were made in *Senecio Fuchsii* ('96), *Centaurea Cyanus* ('96), *C. Jacea* ('96), and *Solidago Virgaurea* ('96), but the number of observations is too small for the determination of the specific characteristics, which was the object of his interest and studies.

II. THEORIES REGARDING THE EVOLUTION AND DEVELOPMENT OF FLOWER NUMBER PER HEAD

A most important conclusion which Ludwig reaches from his studies is that the maxima for the number of ray-flowers and the total number of flowers in the Compositae and the number of rays per umbel in the Umbelliferae all follow the series of Fibonacci (1, 2, 3, 5, 8, 13, 21, etc.), the maxima differing for different species, or for different races of the same species. He sought to relate deviations from this series to the "Nebenzahlen" of the series, i. e., 39, 42, 55, 63, which may be considered as "duplica" or "triplica" of certain of the main series ('97a).

However, in discussing various views regarding phyllotaxy, Ludwig ('97b) suggests the development of other series than the Fibonacci (1/2, 1/3, 2/5, 3/8, 5/13, etc.). The Trientalis, for example, differs in giving the series 1/3, 1/4, 2/7, 3/11, 5/18, etc.

Evolution in regard to flower number was thus held by Ludwig to be discontinuous, so that the various species in a phylogeny represent a series of discontinuous variations with values for flower number which depend on that of the original species.

The number of flowers realized in ontogeny was considered to be determined first by the divisions initiated in the mother organ ("Mutterorgan"), and, second, by the processes that determine phyllotaxy. The suggestion is made that the development of a flower head or of the number of rays involves one complete turn of the spiral. Ludwig, however, does not attempt to correlate flower number with the phyllotaxy of the species, and in the Compositae he does not find maxima that correspond to any other than the Fibonacci series or duplica or triplica of its various numbers.

Ludwig's later ('95) theoretical conceptions of the morphogenetic processes involved in the development of the different numbers of ray-flowers are based chiefly on the observations of Otto Müller ('83) on *Melosira.* In this diatom the individual cells remain attached, forming filaments. The development of the filamentous colony Müller claims to be as follows. Cell division, as always in diatoms, occurs in such a way that of the two daughter cells one is larger. The larger then divides while the smaller one rests. Then the latter divides simultaneously with the larger of the newer pair. Thus one cell divides, giving two; of these, one divides making three cells in the filament; two of these next divide, making five in all; three of these divide next, making eight in all, etc. It is thus claimed that there are rhythmic and periodic divisions in which all the older cells divide together with one half of the newer cells. As a result, the number of cells in the filament increases according to the Fibonacci series, 1, 3, 5, 8, 13, 21, etc.

On the basis of these observations, Ludwig explained the occurrence of maxima for ray-flowers, which he considered to correspond to the series of Fibonacci, on the hypothesis that in the development of such organs as ray-flowers, one part is like the mother organ and another is like the offspring. The mother organ forms new parts in rhythmic succession, the offspring goes through a ripening period and then divides. In Ludwig's own words, "Das Mutterorgan grenzt fortgesetzt in rhythmischer Wiederholung neue Teile ab, der Sprossteil dagegen immer erst in der folgenden Teilungsperiode, nachdem derselbe herangewachsen ist." (Quotation from Vogler, '12.) The term "mother organ" is used vaguely. Whether it is considered as a fertilized egg or as the apical growing-point in the main stem or in lateral stems is not stated. What significance partial variability may have is not discussed.

Ludwig later ('04) brings this conception forward in support of the mutation theory which had then recently been announced by de Vries. The emphasis was laid on the discontinuous increase in the number of cells and organs involved in such rhythmic divisions. In the Compositae, for example, the various species are considered to represent different steps in a series, the number of cell divisions are assumed to stop at certain points and become hereditary. However, in referring to de Vries's studies, later to be discussed here, Ludwig ('04) considers that it is possible to change by cultivation the stage or step which has been reached by a species.

As a theory of morphogenesis, the conception is interesting and suggestive. It is not indicated, however, how a series of rhythmic linear divisions, such as may occur discontinuously in filamentous forms, is to be applied to complex growing-points involving various histogens where various groups of cells are concerned in the production of an organ, as in the case of the formation of a composite flower head, and especially in the application to the number of differentiated ray-flowers constituting only a part of the head. Furthermore, the correlation of characteristic numbers for a species with the phyllotaxy is not attempted.

Weisse ('97) attempts to refer the position and number of flowers in the head to the mechanism of phyllotaxy, as conceived by Schwendener ('78, '85). According to this view, the arrangement of lateral organs, as leaves, is determined by the pressure they exert upon one another when in the embryonic condition. The arrangement and relative position of matured organs is hence not definitely related to divisions taking place in the growing point, but is dependent on the mutual pressures between organs already present and above which the new ones are being formed. Weisse's observations were made on 141 main flower heads of *Helianthus annuus.* The most definite facts revealed are that as the ray-flower number increases more disk-flowers are laid down before two are in contact and that there is much variation in the phyllotaxy immediately below the flower head. There seems to be an increase in ray-flower number with higher values of phyllotaxy, but the great range of variability (13 to 82) in ray-flower number and the small number of cases do not permit of a very definite conclusion.

III. SPECIAL CRITICISMS OF FACTS AND THEORIES

Vogler ('12) discusses especially the theories held by Ludwig. He points out that Ludwig ('87) at first related development of flowers in a head to processes concerned with the mechanism of leaf position, but that as early as 1888 he (Ludwig, '88) refers the phenomenon to certain types of rhythmic cell division which were later more fully formulated by him (Ludwig, '95 and '98). Vogler points out that the two processes (1) the mechanism of phyllotaxy and (2) periodic divisions are not necessarily exclusive, and that leaf arrangement may be due to the same kind of periodic cell-divisions as are involved in the production of flowers in a head.

Furthermore, Vogler ('12) appears to contend that the development of certain numbers as maxima rather than others does not involve the reproduction of Anlagen according to the scheme of Fibonacci, but results from the continuation of the phyllotaxy in the arrangement of the number of parts of the flower head. "Diese Bevorzugung bestimmter Zahlen ist nicht die Folge einer Vermehrung der Anlagen nach dem Schema des Fibonacci, sondern ergiebt sich aus dem gesetzmässigem Anschluss an die Spiralstellung der Blätter." He is evidently led to this view chiefly by his observation that partial variability is strongly in evidence. Also in summarizing the statistical work done in the Compositae, he ('11) finds that only about 85 per cent. of the species exhibit maxima that fall on main and duplica numbers of the Fibonacci series.

Vogler's ('08, '09, '10, '11) original studies on Umbelliferae and Compositae bear directly on the question of maxima and their occurrence according to the law of Fibonacci. His study of the umbellifer *Astrantia major* L. ('08) is of special interest, for here he finds the maxima for the number of bracts, perfect flowers, and male flowers to be lower for lateral umbels than for those on the main stem. In all cases the variability was less for the parts of the lateral umbels than for the main umbels. His conclusion is that the maxima for the parts of the umbels of the main stem follow in general the series of Fibonacci, while those of the lateral stems follow another and quite different series, the Trientalis. Vogler also reports data on the number of ray-flowers in 31,000 heads of *Senecio alpinus* ('09, '10) collected at different localities and at different times of the year. For these the number ranges from 10 to 28 with a maximum at 19, which, as he points out, is not one of the primary or secondary numbers of the Fibonacci series.

In the case of two plants of *Boltonia latisquama*, Vogler ('09, '10) studied the production of flowers in successive years. For three successive years 500 flower heads were counted on each. Although the weather conditions were different in the three years each plant was quite constant in respect to ray-flower number during the three years of observation.

Furthermore, Vogler ('10) undertook in *Arnica montana* and *Eupatorium album* to determine various facts of partial variability, especially the relation of position of heads to variation in the number of ray-flowers. In counts made on ray-flowers of *Arnica montana* in 1909 and 1910, he separated data for terminals and laterals. In both years the terminals gave a higher average ray-flower number than the laterals. In 1909, 266 terminals averaged 14.7, while 153 laterals averaged only 11.6. In 1910 (counts were made in a different locality from that of 1909), 314 terminals averaged 15.1, 149 laterals only 11.1. In both years the maximum for terminals was 13, a number of the Fibonacci series, that for laterals 11, a number of the Trientalis series. More intensive studies were made of partial variability in one plant of *Eupatorium album*. This species has only tubular flowers and the counts were hence made of the total flower number. The plant studied had six branches. On each branch Vogler counted the terminal heads, and then the laterals in succession downward. The most noticeable points brought out by his data are that the flower number is different for the various main branches and that on the same branch the number is different for terminals and laterals, especially for branches near the top of the plant.

A survey of Vogler's work shows that the maxima do not always accord with the series of Fibonacci; they may fall on other numbers such as certain of the Trientalis series. He has also observed and emphasized the significance of partial variability, which he views as evidence against the conception that rhythmic divisions give harmony between mother and daughter organs as to position and number.

IV. EVIDENCE OF INTRASEASONAL VARIABILITY

Some interesting observations regarding intraseasonal variability in number of flowers per head are reported by MacLeod ('99). He found that the ray- and disk-flowers of *Centaurea Cyanus*, *C. alba*, and *C. atropurpurea*, whether from terminal or from lateral heads, are more numerous per head early in the season than later. However, as he studied heads indiscriminately, there are no data on the individual behavior of plants. He grew some of his plants on poor and some on rich soil and found that those on poor soil had a lower flower number per head than those on rich. He rightly points out that experimental breeding work of this kind is necessary in order to determine whether differences are due to heredity or merely to food supply and season.

Tower ('02) reported differences in flower number for heads of *Chrysanthemum Leucanthemum* collected in the same location, but at different dates (July 5 and 30) of the same season. When grouped, such data gave a bimodal curve involving what he calls "secular modes."

Further analysis of intraseasonal variation has been made by Shull. He ('02) made successive collections of heads of *Aster prenanthoides* and counted the bracts and the ray- and disk-flowers per head. The heads were taken from plants growing wild on a "single small plot" and were evidently collected indiscriminately. On the first date of collection records were made from 117 heads, on the second from 143, on the third from 139, and on the last from 116. The average number for all the organs counted decreased in number as the season advanced. Later ('04) he gives data for twelve successive collections, made from September 12 to October 9 in 1903; the curves show low values at first, then a sudden rise, which is followed by a gradual decrease and a sudden rise at the end of the season. The rise at the end of the season can hardly be considered to be significant, since it was determined from only four heads. Shull attributes seasonal variability here observed chiefly to individual variability rather than to partial variability. He suggests that the low flower number seen early in the season is due to weak or starved individuals which bloom first and which have a lower flower number than is normal for the species, but his data being indiscriminate do not determine the facts regarding this point. Further, his view raises the question of the adequacy of judging vigor by the number of flowers per head. The data later presented in this paper for chicory will show that partial variability may have been involved as the principal cause of the seasonal decrease observed by Shull.

V. OBSERVATIONS AND EXPERIMENTS ON THE INFLUENCE OF ENVIRONMENT

With the recognition that the number of parts in an inflorescence is often subject to considerable variability, certain experimental studies were made regarding the influence of nutrition. Some of these have a very direct bearing on the factors involved in both individual and partial variability.

Weisse ('97) sowed seeds of two heads of *Helianthus annuus;* half of the seeds of each was sown in pots containing sand, and half was sown in ordinary garden soil. The ray-flowers in the terminal heads were counted. The 155 heads from plants grown in sand had an average ray-flower number of 21 and a standard deviation of ±6.6. The 221 heads from plants grown in the garden had an average ray-flower number of 37 and a standard deviation of ±9.2. These differences observed were quite evidently due to the effect of nutrition. A point that is of interest and that Weisse does not call attention to is the smaller variability of the starved plants. Weisse states further that certain plants that were heavily manured had as many as 82 ray-flowers in a head and a maximum at 55; while heads with less than 30 ray-flowers usually were found on plants which were checked and retarded in growth by the crowding of neighboring plants. Weisse combines the data obtained from the two cultures, the one on sand and the other on garden soil, and points out that the resulting bimodal curve, having a maximum at 21 and one at 34, is a result of different nutritional conditions under which the population was grown. He believes such conditions might readily occur in nature and that bimodal curves that have been ascribed to the mixture of two races are often due to differences in nutrition occurring in nature.

MacLeod ('99) published some observations on *Centaurea atropurpurea* which show the effect of nutrition on the number of ray- and disk-flowers. Here again there is a lower flower number under conditions of poor nutrition, but the number of disk-flowers seems to be more affected than that of ray-flowers. MacLeod gives only the averages for each culture, so that the variabilities of the cultures cannot be determined.

De Vries ('01) repeatedly states that favorable environmental conditions, such as optimum water-supply and manuring, tend to increase the size of organs (fruits of *Oenothera*) and the number of parts, as the number of rays in the umbels of Umbelliferae or the ray-flowers in the heads of Compositae.

Danforth ('08) comparing ray-flowers of the daisy growing in a well-drained situation with those in a drier situation, reports a lower mean and less variability for the latter. Koriba ('08) made successive collections of heads of *Arnica unalaschensis* (also some other Composites) from two different localities, one from a valley and the other from the slope of a mountain. Those on the slopes were growing under the least favorable conditions and gave uniformly lower values.

Detailed studies by Burkill ('95) show that the number of stamens in flowers of *Stellaria media* increases during the first two weeks of bloom, then there is a gradual decrease to the end of the flowering season. Reinöhl ('03) working with the same plant showed further that the plants grown in poor soil produced flowers with a lower number of stamens. Tammes's ('05) studies of the effect of good and poor soil conditions on various characters show lower values for many of the characters of poorly nourished plants. Love's researches ('11) are among the most recent that deal with the effect of nutrition on the mean of such characters as height, number of peas per pod, weight of seeds, etc., in such plants as peas, buckwheat, and corn. His results agree with those mentioned above, that is, he finds an increase in the mean and in the variability, as a result of better nutrition.

VI. STUDIES OF INTERANNUAL VARIABILITY

In the consideration of interannual variability, at least two distinct aspects are to be recognized. First, the season of growth may differ in a way that affects the plant, and, second, in the case of perennial plants the age of the plant may be a factor in variability just as the period of development may influence the partial variability seen in a single year of growth. These two factors have rarely been distinguished and little attention has been directed to the factor of age, for flower number studies have been chiefly indiscriminate for the population.

Haacke ('96), it seems, is the only investigator who has attributed variation in the number of ray-flowers of composites to the age of the plant. He suggests that older plants probably have more ray-flowers per head. His observations on *Chrysanthemum Leucanthemum* and *Anthemis arvensis* were not conclusive, however, for he did not know the age of the plants studied.

Yule ('02) gives the results of counts made in three successive years of the number of sepals in a population of *Anemone nemorosa* from one habitat. He gets differences in the means for different years and calls attention to the importance of observing "local races" for several years before one can determine the characteristics of a species. Shull ('04) made a similar study for a population of *Aster prenanthoides* and obtained higher mean values for bracts, rays, and disk-flowers for 1900 than for 1903. He attributes this to more favorable climatic conditions in 1900 and points out the importance of taking differences due to climate into account in determining "place constants."

Clark ('10), working with timothy, calculated coefficients of correlation for the same character in different years. Following Tower he calls these coefficients of "place variation." He correlates height in 1905 with that in 1906, height in 1906 with that in 1907, and height in 1905 with that in 1907. He does the same with weight. He finds considerable correlation, which means that in spite of varying conditions, such as climate, plants high in values one year will be high the next.

Harris ('15) has recently called attention to the different values of interannual correlation for different characters. This study gives a comparison of data of the same sort for successive years by means of correlation tables, as Clark ('10) has done in the paper just mentioned. The degree of relation is then expressed by the coefficient of correlation. This method has been used especially in studies on growth in man (Boas and Wissler '05), and Harris refers to work of Pearl and Surface on egg-production and Gavin on milk records, where interannual coefficients of correlation were used. Harris published data for interannual correlations for fruits of *Staphylea trifolia* and *Hibiscus syriacus* in which he gets various degrees of correlation according to the parts of the fruit studied; for example, for 23 fruits of *Hibiscus* he finds the correlation for 1907 and 1908 to be for sepals and sepals +0.46, for bracts and bracts +0.84, for ovules and ovules +0.94, for seeds and seeds +0.63, etc. While these studies indicate that the degree of correlation may be different for different characters, they are not especially concerned with the analysis of changes in values for a single character due to such a factor as age.

VII. EVIDENCE THAT POSITION IS A FACTOR IN PARTIAL VARIABILITY

With the recognition of the existence of partial variability there developed further refinement of study which aimed to determine the relation of position on a plant to difference in number of parts. Burkill ('95) gives indiscriminate data for 102 flowers of *Caltha palustris* which indicate that the number of stamens and carpels is larger in terminal flowers than in laterals.

Haacke ('96) made a detailed study of ray-flower number of *Tanacetum corymbosum*, taking into account the position of the heads on the plant. He studied 81 plants and presents data for each plant separately. The largest number of heads for a single plant recorded is 14. There is one flower head at the end of the main stem, which he calls primary. There are, on the average, four or five unbranched branches each bearing a terminal head. These he calls secondary heads. There usually follow several branched branches, which bear secondary and several tertiary flower heads. The lower branches of the plant are longest, thickest, most branched and the secondary heads on these branches are about the same distance from the ground as the primary head. In other words, the lower branches have the greatest similarity to the plant as a whole. He found that the primary head had on the average the highest number of ray-flowers, the secondary head of the first branch the lowest. There was then an increase in the number of ray-flowers of successive secondary heads. From the tenth branch downwards the number of ray-flowers of the secondary heads was the same as that of the primary head. There was a correlation between ray-flower number in the primary head and of the secondary and tertiary heads; those plants having high or low numbers in the primary had correspondingly high or low numbers in the others.

MacLeod ('99) made a similar study of the flower heads of *Centaurea atropurpurea*. He does not, however, keep the data for individual plants apart and his results are not as clear as those of Haacke. He first counted the terminal heads of the main axes, 424 in all. The average total number of flowers (disk and ray) in these was 47.7. He then examined the heads on the branches. Of these the first group consisted of 524 heads in bloom between July 10 and 12. These had an average flower number of 39.2, considerably lower than the average for terminal heads. He calls this a "bud-generation" (knopgeneratien). After seven days he cut off all the open flower heads, and his second "bud-generation" consisted of 656 heads blooming from July 21–25, and with an average flower number of 34.4 flowers per head. He continued in this way to the end of the flowering season and got a decrease in flower number in successive "bud-generations." The only fact revealed that clearly bears on the question of flower number in relation to position is that there appears to be a higher flower number for terminal heads than for those borne on side-branches.

Schüepp ('13) has made detailed statistical studies on *Aconitum Napellus*. One of his chapters is devoted to variations within the individual (partial variability) and his data show that to a certain extent quantitative characters are functions of the position of the organ on the plant. This is very apparent for a character like leaves, which in the vegetative parts are petioled, large, and have 40–50 points, while in the reproductive regions they are sessile, small, and one-pointed. He also gives the number of perianth parts, nectaries, stamens, and carpels for three regions, base, middle, and top of plant, and in all finds a slight decrease in the number of parts from the base upward.

Klebs ('06) showed that there were slight differences between lateral and terminal inflorescences in *Sempervivum*. Vogler ('12), whose work has been discussed earlier, presents data to show differences according to position between number of flowers in the inflorescences of Umbelliferae and Compositae.

Such differences as have been noted have a bearing on the much larger question of the periodicity shown in the development of an individual plant. Braun, Sachs, van Tieghem, J. W. von Mohl, and de Vries have contributed much to this question. Tammes ('03) reviews the literature on this subject and gives to von Mohl the credit of establishing the fact that there is a periodicity in cell division, so that the longer internodes have more as well as longer cells than the shorter. Tammes ('03) investigated a large number of plants and showed that there is a periodicity in development for length and breadth of leaves, length of petioles, and number of main veins.

These studies show that partial variability in respect to the number of parts in a complex structure such as a flower or a flower head is to some degree related to position on a plant involving time of development, and therefore introduces an element of differentiation. This places an emphasis on processes of development which give a periodicity or a sort of polarity. The processes assigned by such conceptions as that of Ludwig to rhythmic cell divisions which give specific differences for species as such may themselves undergo change, continuous or discontinuous, in the development of successive parts of a single individual.

VIII. SPECIAL VIEWS REGARDING HEREDITY, DIFFERENTIATION, AND SYMMETRY, HELD BY PEARSON AND BY BATESON

While Pearson's studies of numerical qualities in plants do not pertain to number of flowers in any of the composites, they are of special interest in the recognition that differentiation is a factor in partial variability seen among organs of the same kind. They also illustrate very well the difficulties of adequately determining the heredity of such a character as the number of stigmatic bands or seed chambers in fruits of poppies, of *Nigella hispanica*, and of *Malva rotundifolia*.

Pearson's earlier report ('01) bears on the statistical and mathematical demonstration that "undifferentiated like organs" or "homotypes" on an individual are alike only to a certain degree. The degree of likeness between homotypes as measured by his methods of determining homotypic correlation, has on the average a mean value of 0.4–0.5, which is, he considers, quite identical with the general value for fraternal correlation. Thus he concludes that heredity is a phase of homotyposis and that the sources of variability are to be sought in the individual. The distinction between differentiated and undifferentiated like organs is not, Pearson recognizes, always easy to make. In general, the former class involves function, position on the individual, season of production, etc., and is statistically discoverable by testing the frequency distribution for heterogeneity. In contrast to this, Pearson distinguishes variability of "undifferentiated like organs" as due to "that combination of small causes, inherent and environmental, which leads to what is familiar in both theory and observation as a homogeneous chance distribution" (p. 287).

We may note that when such differentiations as exist in the poppy and in *Nigella* are thus treated as pure chance variations the statistical treatment may give a high or low value for homotyposis. The existence of differentiation is not necessarily revealed by such treatment of data. It is to be determined only by observation and by a refinement of methods of collecting data.

Pearson's first studies ('02b) pertaining to the heredity of the number of stigmatic bands in capsules of the Shirley poppy are of special interest, for here data were collected from all capsules. These data were statistically treated by three methods:

1. The correlation of all offspring capsules with parental mean capsule, the various progenies grown in each locality being thrown together in a single correlation table.

2. The comparison of the average variability of an array of offspring of a single parent plant with the variability of the offspring population. Here the means for individual offspring were determined.

3. A mathematical consideration of homotypic relationship in correcting the parental correlation determined by the first method.

According to the first method the parental correlations for the different crops, as a whole, range from 0.3230 to 0.1220. The highest correlation of 0.3230 was obtained in the "most starveling crop" which had few capsules per plant and the low correlation of 0.1220 was obtained in the crop that was most luxuriant in growth. Here is definite evidence that the greater vigor of growth affects individual variability by increasing very much the partial variability. On this account the method of collecting data and the statistical treatment give lower parental correlation when there is increased vigor.

In one crop of 907 plants the means were determined separately for each plant and these were correlated with the mean of the parents. The value was 0.1561 as compared with 0.1864 obtained for the same crop by the first method. Here Pearson attributes the low parental correlation to "differentiation" and reports that the flowers that come out "early in the season have fewer bands than those which come later" and that "the number of capsules to the individual plant, and the dates at which it produces them, tend to obscure the influence of pure heredity, and make the stigmata, however easy to count and deal with a by no means ideal character to study heredity upon" (p. 72).

The low values obtained for parental correlation were, however, not considered as correct because homotyposis was involved. The true parental correlation, according to Pearson's conception, was higher. By accounting for homotyposis the value was raised from the average of 0.20 to a value lying between 0.35 and 0.40.

It would seem that much of the difficulty here experienced in attempts to make exact determination of values, even for populations such as Pearson studied, lies in treatment of all the variations as "chance." Although Pearson definitely recognizes that lateral flowers are differentiated from terminals, there is no attempt to determine values for such partial variability.

In further studying heredity of number per capsule in the poppy, Pearson ('**06**) sought to avoid the difficulties previously encountered in estimating the individual when multiple observations involving partial variability were made. He attempted to do this by "confining the attention to the first or principal flower." In 1903 and 1904, crops were grown from seed of random samples in 15 different localities and treated as populations. Differences in mean and in variability were found which were attributed to effects of environment as affecting individual variability and which were so great as to be "not directly comparable." It was possible to determine parental correlations for these results in only one population; a crop grown in 1904 from parents of a 1903 crop, the two crops, however, were grown at different localities. The raw correlation was only 0.1717.

Pearson therefore concludes that the determination of heredity even for such an easily measured quality as the number of stigmatic bands in pods of the poppy is exceedingly complex and difficult, and he now questions "whether the apical flower is as true a measure of individuality as the totality of flowers on the plant" ('**06**, p. 400).

Pearson is here concerned with population studies and in intensity of parental correlation for rather mixed populations. His treatment and results suggest and in fact reveal many sources of variability. His rather uncertain results raise very definitely the question of how to value adequately a numerical character which exhibits elements of both chance and differential variability for both partial and individual variations.

Bateson ('**01**, '**03**) questions the validity of Pearson's distinction between "chance variation" and "differentiation" in the treatment of homotyposis and heredity. He insists that "meristic" variations are discontinuous and doubts that "there is a true material distinction between variation and differentiation as applied to parts of the same organism." Bateson further objects to a comparison of "undifferentiated like organs" with the correlation between brothers which may be differentiated as individuals. He evidently views the partial meristic differences of organs of the same kind actually in evidence in such plants as *Nigella, Cichorium,* etc., as a differentiation of the same rank as differentiation between individuals as such ('03, p. 23). Bateson emphasizes the aspects of symmetry, advocates an extreme view that tissues and organs arise somatically by "differentiant or segregating divisions" in much the same sense as Weismann postulated, and he thus questions the adequacy of the term "chance variations." He is perhaps strongly influenced by his earlier studies of meristic variations in animals in which differentiation and symmetry are in marked evidence, and by the views of segregation of hereditary units representing characters which may give differentiation between individuals of the same hybrid origin.

IX. EVIDENCE OF HEREDITARY VARIATIONS

There appears to be no report of researches directed to the study of selection and heredity involving only total flower number per head in any of the Compositae. There are, of course, many species in cultivation from which double-flowered varieties have been developed, the history of which does not involve statistical studies of total flower number. Moreover, the development of so-called double-flowered composites does not necessarily involve increase or decrease of total flowers per head, but a change of such flowers as tubular disk-flowers into strap-shaped or ligulate flowers more like the ray-flowers.

The studies of de Vries ('01) on *Chrysanthemum segetum* are of interest in their bearing on selection, heredity, and evolution of flower number. He first isolated a race having a maximum of 13 ray-flowers in the terminal heads. Then he isolated a race with 21 ray-flowers in the terminal head. In this case, however, he considered it necessary to judge his plants not only by the ray-flower number of the terminal heads, but also by the ray-flower number of the later heads, for he found that some plants having 21 ray-flowers in the main head gave for all flower heads curves with maxima lower than 21, often at 13 or 14. These plants were discarded as not belonging to the desired race and only those giving "partial curves" (the curves obtained from the flower heads on a plant) with maxima at 21 were retained. No attempts were made to isolate races with numbers intermediate between 13 and 21, and no further studies were made of the very irregular cases of partial variability which were in evidence.

After isolating the two races, de Vries observed variation in the race with 21 ray-flowers in terminal heads in respect to increase of ray-flowers. In a crop of 1,500 plants one was found with each of four lateral heads having 22 ray-flowers, a higher number by one than was previously seen in any of the terminal heads. Open-fertilized seed of this plant gave a progeny in 1897 of 414 plants; the number of ray-flowers in terminal heads ranged from 14 to 34. From seed of the plant having 34 ray-flowers in 1898, 241 plants were grown; for these the range was 19 to 48; the modes were at 26 and 34. The average of the population was 38. The next year 194 plants, offspring of the plant with 48 ray-flowers, produced terminals with ray-flowers ranging from 19 to 67; the modes were scarcely pronounced at 32, 37, and 45, and the average number of rays was 41.5. In this crop, it is stated, ligulate flowers appeared among the disk-flowers in one head of 62 ray-flowers. The seed of this plant gave a progeny in 1900, 31 plants in all, ranging in ligulate flowers of terminal heads from 33 to 101; there were no pronounced modes either primary or secondary; the average number was 53.2. One plant had some heads with only ligulate flowers.

Evidently for the first few years there was an increase in the size of the heads and the accompanying number of ray-flowers. Then there came also a change of disk-flowers to ray-flowers. Throughout there had been great irregularity in heredity revealed in range of numbers observed in individual variability both for data of terminals alone or for terminals and laterals. Such variation de Vries assigns to mutation and attempts to show that the increase in number follows the Fibonacci series. There can be no doubt that spontaneous variations here occurred, giving increased variability, and that selection of the extremes was effective in giving a new race.

X. PREVIOUS STUDY OF FLOWER NUMBER IN CICHORIUM INTYBUS

It appears that the only statistical study of flower number in a species in which the flowers are all ligulate is that of de Helguero ('06).

His data were obtained from *Cichorium Intybus.* He counted the flowers in 1,000 heads produced by 624 individuals; the counts were made on five different dates during August when the plants were approaching the end of the blooming period. "Le piante furono raccolte in 5 diverse volte durante il mese di Agosto e percio nel periodo decrescente della fioritura." Of the total 1,000 heads, 389 were from 389 plants which had only one head each in bloom at the time of collection: 300 heads were from 150 plants having two heads each in bloom when the counts were made: 311 heads were from 85 plants having 3 heads open on a single date. The data are treated almost solely to determine homotyposis. The table of correlation for the 150 pairs (two heads for each plant paired) gives a correlation of +0.5915. The correlation table for all pairing of two or more per plant gave a correlation of + 0.6130. The results show that when a few heads (in most cases only two) are taken from a plant on a single date at the end of the blooming period the correlation is about +0.6. De Helguero did not extend his observations sufficiently to determine adequate values for partial and individual variabilities.

XI. SUMMARY

Statistical studies of such a numerical character as number of parts in an inflorescence were initiated about twenty five years ago by the very general collection of data from mixed populations. The method was to study species *en masse.* The chief aim was to discover specific qualities. Broad generalizations were made (1) that flower number is specific for species, (2) that the numbers characteristic of species fall in a series such as that of Fibonacci, and (3) that evolution giving such differences has been discontinuous. The further important conclusion was reached that such discontinuous specific differentiation arises through processes operating in the development of the individual and these processes were assumed to involve rhythmic cell divisions. It was also suggested that there is a relation between flower number and phyllotaxy.

It was early recognized, however, that the maxima for species do not all fall in a well-defined series and hence attempts were made to show that in such cases other series were represented. From the first, it was evident that there was often a wide range of variation in flower number in a species, but the view was taken that the variations within a species or a race were solely due to chance, and that the facts could be accurately determined by Galtonian treatment of populations.

The more recent work has been very generally directed to the study of variation within a species. Processes operating within the population have received attention. Studies have become more particular and individual in scope. Various hitherto unrevealed sources of variability, intraseasonal, interseasonal, environmental, racial, individual, and partial were thus demonstrated.

To the present time, however, these studies have been largely dominated by the view that the variations are those of chance. The demonstration in a few cases that such variations, especially partial, are not purely due to chance, but may proceed in a discoverable manner, has revealed a source of possible error in much of the work done and emphasizes the desirability of combining extensive studies with a study of the organization of individuals as units.

It seems clear that intensive studies of individual and partial variabilities should serve as a basis for extensive study of species as such. Through such methods we may hope more adequately to determine the facts which serve as a basis of judgment regarding the processes operating in ontogeny, phylogeny, and evolution.

THE PROBLEMS IN CICHORIUM INTYBUS

The statistical studies here reported for *Cichorium Intybus* were begun with the aim of determining the facts as to partial and individual variability for such a character as the total number of flowers produced per head. The nature of the partial variabilities was found to be such as to afford special opportunities for analyses of the intraseasonal and interannual variability and for a study of variation among heads according to position on a plant. The data were so collected that individual variabilities could also be determined. As the studies progressed interest extended to a study of heredity and the effects of selection in the different races which appeared and which were grown in pedigreed cultures.

MATERIAL AND METHODS

Cichorium Intybus is in many respects especially favorable for such study. The flowers are conspicuous and with the exception of an occasional tubular flower are all ligulate. The flowers of a head are readily distinguished and easily counted, as all the flowers of a head are fully expanded at the same time. A head opens but once and is usually expanded but a few hours during the forenoon, a behavior that somewhat limits the amount of data that can be collected in a day, but makes the collection of data from day to day more simple, as there is no danger of recounting the same heads. The flower number per head is not excessively high, which with the disposition of expanded flowers makes accurate counts a simple matter. A considerable number of flower heads open each day during a rather extended period of blooming. The numbers during the greater part of the season are sufficient to give at least ten heads per day for study. The abundant branching and the development of a large number of heads in various positions and at various times admits of rather full development of numerous parts of an individual and gives opportunity for the intensive study of various aspects of partial variability. The plants are, furthermore, hardy and easy to cultivate, so that numerous plants can be grown under as nearly the same conditions as is possible.

The cultures of *Cichorium Intybus* studied were, for the most part, the same plants whose behavior in respect to sterility (due to physiological incompatibility) has already been reported (Stout, **'16**, **'17**); they include mainly two somewhat distinct groups of plants, as follows:

In one group are F_1, F_2, F_3, and F_4 generations derived by crossing plants of wild white-flowered chicory and plants of the unimproved cultivated variety known as Barbe de Capucin. Some study was made of a few plants of the parent stock. The wild white-flowered parents (designated as *A* and *C*) were obtained in the autumn of 1911 from the campus of the University of Wisconsin and transplanted to the experimental plots at the New York Botanical Garden. In 1912 a crop of plants was grown from the open-fertilized seeds of these two plants. Plants of the variety Barbe de Capucin were grown in 1912 from seed obtained from J. M. Thorburn and Company (no. 4300, catalogue of 1911). These plants are designated the *E* series. All the plants of the first crop, of both wild and cultivated strains which were experimentally tested for self-fertility, were found to be self-sterile from physiological incompatibility. Crosses were made involving two plants of wild stock (*A* and *C*) and two plants of Barbe de Capucin (E_3 and E_{22}). Some of the F_1 progeny were self-fertile (Stout, 1916), and from these several self-fertilized lines of descent have now been grown in F_2, F_3, and F_4 generations and utilized in the statistical studies. The greater number of races and lines of descent reported later are descended from a single cross between a wild white-flowered plant (*A*) and one of the variety Barbe de Capucin (E_{22}).

Considerable data were also collected from plants of the inbred generations of a salad variety known as improved red-leaved Treviso, the seed of which was produced by the firm of Ernst Benary of Erfurt, Germany, and supplied by J. M. Thorburn and Company. One generation of 50 plants, F_1 hybrids between plants of red-leaved Treviso and the wild white-flowered plant *A* have also been studied. It should be stated that the seeds for all the cultures of chicory here reported have been sown in sterilized soil in small pans during the months of December and January, the young seedlings were transplanted to pots all properly labeled and grown in the greenhouse until the first of April, when they were transferred to cold frames. By the middle of May, when planted in the field, the plants as a rule have formed vigorous rosettes often more than a foot in diameter. With this treatment nearly all plants come into bloom in the first year of growth.

The plants of the Treviso strain, as well as such varieties as improved large-leaved, improved white-leaved, and improved spotted, when treated this way come into heavy bloom and die as annuals. The plants of the Treviso strain have therefore been studied in only one year of bloom.

The preliminary studies of 1912 indicated that usually there is such a marked decrease in flower number per head as the season advances that data which are to be considered adequate should be taken during the entire flowering season. Hence, in the collection of data here reported, the method has been to begin on the first day of blooming and to continue throughout the season, obtaining counts of ten heads per plant, when that number was in bloom, on each of at least ten different dates per month at intervals of every third day, or as close to that schedule as conditions allowed. The flower heads counted were taken at random from various branches on the plant and from various parts of the different branches. The heads selected were usually removed, the flowers counted, and the number recorded on sheets specially ruled and tabulated for dates and numbers. In 1913 and 1914, many data were also taken on the character of each flower as to whether ligulate or tubular, as to number of teeth in the ligule and the depth of lobing. In 1915 and 1916 data were secured for flower number only. Special methods were used to obtain certain data; for all plants studied in 1915 data were taken every day during the first twenty days of blooming; and on five plants data were taken on all flower heads (excepting those that opened on Sundays or on days of heavy rainfall) with reference to their position on the various branches of the plant; this was done to determine more exactly the relation of position to time of blooming and to the intraseasonal change in number, both of which appear in the data as more generally collected. Data have been collected from a few individual plants during four successive years of growth, but the greater number of plants have been studied in the first of bloom.

Considering all plants of all stock, in 1913 data were collected from 63 plants, in 1914 from 110, in 1915 from 351, and in 1916 from 450. The total number of individual plants involved is 832. The number of heads counted approximates 5,500 in 1913, 20,000 in 1914, 113,000 in 1915 (including here data collected every day for first 20 days of bloom), and 95,000 in 1916, making a grand total of about 233,500. The total number of individual flowers counted during the four years is about 4,200,000.

The collection of these data has taken much time and has involved the coöperation of several persons, as follows: In 1913, Dr. Joseph C. Gilman and Mr. Allen C. Fraser assisted the senior author of this paper in the collection of data. In 1914, Miss Friedolina C. Jud and Mr. Allen C. Fraser assisted the joint authors of this paper. In 1915, Miss Jud and Mr. R. C. Faulwetter assisted the writers. In 1916, Mr. M. V. Reed assisted during the months of July and August. In 1914, 1915, and 1916, Mr. Charles Holste, who was gardener in charge of the experimental plots, frequently assisted, especially when the work was pressing. Dr. Gilman in 1913, Mr. Fraser in 1914, Miss Jud and Mr. Faulwetter in 1915, and Mr. Reed in 1916 were recipients of scholarship grants from the Garden. In July, 1914, Miss Boas, joint author in the production of this paper, became a member of the Garden staff and took charge of the compilation and special methods of statistical treatment of the data. Miss Boas has made all the computations involved in this report and has assisted very materially in the search of literature. For the greater portion of the text, for critical discussions of literature, for discussion of results, and for opinions expressed in this paper the senior author is responsible.

Special care has been taken to insure uniform methods in the collection of data and the persons assisting collected from the same plants continuously at least during the period of their coöperation.

The somewhat laborious work of collecting such a large amount of data has been possible only through the hearty coöperation of the persons above mentioned. The authors wish here to express their appreciation of this coöperation and of the support of Dr. N. L. Britton, Director-in-Chief, in granting the scholarships as noted.

PRESENTATION OF DATA FOR FLOWER NUMBER IN CHICORY

I. GENERAL SURVEY OF THE KINDS OF VARIABILITY PRESENT

1. PARTIAL VARIABILITY

A. *Intraseasonal partial variability.*

The collection of random data on successive dates from individual plants reveals that, as a rule, there is a marked decrease in flower number per head as the period of flowering advances. Differences in number per head appear according to the stage of development of the plant as a whole.

The seasonal performance of a plant, as shown in such tables as 1 and 2, indicates that the number of flowers per head in heads as they appear from day to day is much higher during the early period of bloom than in the last days of bloom. This is indicated by both the daily range and the daily average. The change, however, is rather uniform and progressive as the season advances.

Partial variability, or variation among the apparently homologous heads produced by a single plant, is therefore seen in the range of the number per head; in TABLE 2 the range is from 12 to 23. But the daily data show that the range of values and the average value shifts from day to day. The variations from day to day are not therefore solely chance variations, since certain elements of differentiation appear.

The totals of all heads with the same number of flowers give what appears as a chance distribution. The chance collection of data for any period of time, as the first ten days, the second ten days, etc., would also give general summaries that would appear as chance variations; that such data do not adequately represent the individual seasonal performance is, however, very obvious. Random collections would hardly reveal the presence of intraseasonal variation; it is only the tabulation and computation of data for individual days from individual plants that clearly brings out such facts.

For the sake of completeness, there are given with the tables values whose significance will become clear later on. It is sufficient to point out here that *a* is the computed flower number for

TABLE 1

SEASONAL DISTRIBUTION OF FLOWER NUMBER PER HEAD FOR PLANT E_3 OF BARBE DE CAPUCIN TWO YEARS OLD. DATA FOR 1913

Number of flowers per head	June			July														August								September		Total
	26	27	28	1	3	7	9	11	14	16	19	21	22	24	26	29	31	2	5	9	12	15	20	25	29	1	8	
14	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2	....	....	....	....	....	....	....	2	4
15	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2	....	1	1	....	1	....	2	2	2	3	....	14
16	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	2	....	....	1	4	2	5	3	1	4	3	2	28
17	....	....	....	....	....	....	....	1	....	....	....	....	....	2	2	....	3	3	4	2	5	1	3	3	1	1	4	35
18	....	....	....	....	....	....	....	3	1	....	....	1	....	2	2	2	....	1	1	4	4	3	1	3	....	2	....	30
19	....	....	2	3	2	5	4	4	2	4	6	5	....	1	3	2	3	3	1	....	....	1	1	....	2	1	2	57
20	....	7	10	2	6	5	4	2	5	3	3	2	....	4	2	1	4	....	....	....	....	....	....	....	....	....	....	60
21	6	6	9	9	1	....	1	....	....	....	2	....	2	....	....	....	....	....	....	....	....	....	....	1	....	....	....	37
22	3	....	1	1	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6
23	....	....	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2
Averages..	21.4	20.5	20.5	20.7	19.9	19.5	19.9	18.7	19.5	19.4	19.6	19.1	21.0	18.8	18.3	17.3	18.8	17.6	16.4	17.0	17.0	17.0	16.6	17.2	16.6	16.5	16.6	273

$[o] = 18.6$ $\qquad a = 20.6$

$[ot] = -24.49$ $\qquad b = -0.064$

$[t] = 31$ $\qquad t = 74$

$[t^2] = 441.96$

TABLE 2

SEASONAL DISTRIBUTION OF FLOWER NUMBER PER HEAD FOR PLANT E_3 OF BARBE DE CAPUCIN THREE YEARS OLD. DATA FOR 1914

Number of flowers per head	July								August												September											October				Total
	10	11	17	18	20	22	27	30	1	4	6	10	12	15	17	19	21	24	26	31	3	8	10	12	15	17	22	24	26	28	30	2	5	7	9	
12	..	..	..	..	..	..	..	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	1
13	..	..	..	..	..	..	..	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	1
14	..	..	..	..	..	..	..	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	1	...	2
15	..	..	..	..	..	..	..	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	1	...	...	...	1	...	...	...	...	1	...	1	...	5
16	..	..	..	..	..	..	..	...	...	...	...	...	...	...	...	...	1	...	...	1	...	...	...	...	...	1	1	...	2	1	...	...	...	...	...	7
17	..	..	..	..	..	..	..	...	...	...	...	...	...	1	...	...	1	2	...	1	...	...	3	2	3	1	1	1	2	...	3	1	...	1	1	24
18	..	..	..	..	..	..	..	...	...	2	...	...	...	...	...	1	4	1	2	3	2	...	1	...	1	...	1	2	1	4	2	...	2	...	5	34
19	..	..	1	1	..	1	4	2	2	1	2	3	3	4	3	1	2	1	4	1	4	5	3	7	4	4	4	7	4	1	4	5	6	5	2	101
20	..	..	4	5	3	4	3	6	4	3	2	3	5	3	6	2	1	...	3	5	3	3	2	2	1	4	1	...	2	5	...	3	2	1	1	92
21	4	2	4	1	6	3	2	1	2	4	6	4	2	2	...	2	1	...	...	...	1	1	...	...	...	...	...	...	...	...	...	...	...	...	...	48
22	..	..	1	..	..	..	..	...	...	...	...	..	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2
23	1	..	..	..	..	1	..	...	2	...	...	..	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4
Av.	21.4	21.0	20.5	20.0	20.7	20.6	19.8	19.9	20.6	19.9	20.4	20.1	19.9	19.5	19.9	19.9	18.4	17.7	19.1	18.4	19.3	19.6	18.1	18.8	17.9	18.9	18.0	18.6	18.2	18.8	17.6	18.7	19.0	17.9	17.7	321

$[o] = 19.2$ $a = 20.7$

$[ot] = -24.36$ $b = -0.032$

$[t] = 47$ $t = 91$

$[t^2] = 801.71$

TABLE 3

SEASONAL DISTRIBUTION OF FLOWER NUMBER PER HEAD FOR FIRST YEAR OF BLOOM OF AN F_1 GENERATION PLANT ($E_{22} \times A$)–*10–ser. I, no. 5*, DERIVED FROM A CROSS BETWEEN A PLANT OF BARBE DE CAPUCIN (E_{22}) AND THE WILD PLANT (A). DATA FOR 1915

Number of flowers per head	September																				October							November		Total
	4	6	7	8	9	10	11	13	14	15	16	17	20	22	23	24	25	27	28	29	6	9	13	16	19	22	26	1	4	
15	...	...	1	...	...	3	2	...	1	...	1	...	...	1	...	...	1	...	...	...	1	...	1	1	1	...	...	...	1	15
16	...	4	1	3	2	5	4	2	2	2	2	3	3	1	1	1	3	...	...	3	3	3	3	5	...	1	...	...	1	58
17	...	3	4	3	4	1	4	4	4	6	6	4	2	5	2	3	4	6	5	3	3	4	4	2	2	...	2	2	3	95
18	1	3	2	1	1	1	...	2	3	1	1	3	3	3	4	4	1	2	4	2	1	2	1	1	1	1	1	...	...	50
19	...	...	...	3	2	...	...	2	...	1	...	...	4	...	3	2	1	2	1	2	...	1	...	...	...	2	2	...	...	28
20	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	2
Averages..	18.0	16.9	16.9	17.4	17.6	16.0	16.2	17.4	16.9	17.1	16.7	17.0	17.6	17.0	17.9	17.7	16.8	17.6	17.6	17.3	16.9	17.1	16.6	17.3	16.7	18.0	17.7	17.0	16.4	248

$[o] = 17.2$ $a = 17.1$
$[ot] = +1.33$ $b = +0.004$
$[t] = 29$ $t = 61$
$[t^2] = 310.79$

the first day of blooming, *b* the calculated rate of decrease per day, and *t* the number of days the plant was in flower. [*o*] represents the average flower number of the plant, calculated as are all the other values, from data collected throughout the flowering period.

Exceptions to the general rule of seasonal decrease occur. One of these is indicated in the performance record given in TABLE 3. The marked feature here is the decided uniformity in both range and average number of flowers per head throughout the entire period of bloom.

The plant here considered (TABLE 3) bloomed for a period of two months. The total number of heads counted was 248. The partial variability seen in the range of 15 to 20 was quite indiscriminate and coëxistent as to time. As the season advanced there was no appreciable change and the computed value for the rate of decrease is +0.004, a slight increase.

Data of another plant showing no intraseasonal decrease are presented in TABLE 4. Here there is, as in TABLE 3, no noticeable change in the general average or range from day to day, except for a few irregularities at the beginning and end of bloom in which the values usually obtained are reversed; the very lowest numbers per head appearing on the first two days of bloom.

In a few cases there is a decided though small increase from the beginning to the end of the season. The greatest increase observed was +0.025. In all these cases the plants had a low flower number throughout the season. TABLE 31 gives data for one of these plants.

A further variation in seasonal performance is shown by data of TABLE 15. Here there is a marked decrease both in the range and in the average of flowers per head, but the lower numbers of the range remain quite the same throughout; the shifting involves chiefly the higher numbers.

B. *Interannual partial variability.*

The collection of data from the same plant in successive years makes possible a comparison of the performance of an individual in different years in which the seasonal and growth conditions may be different, and in which the different ages of the plant may also give differences in vigor involving differences in time of blooming, all influencing the performance of the season.

TABLE 4

Seasonal distribution of flower number per head for first year of bloom of a F_1 generation plant $(E_{22} \times A)$—*10—ser. I, no. 4*, derived from a cross between a plant of Barbe de Capucin (E_{22}) and the wild plant (A). Data for 1915

Number of flowers per head	September																			October									Total
	8	9	10	11	13	14	15	16	17	18	20	22	23	24	25	27	28	29	30	1	4	6	9	13	16	19	22	26	
12	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2
13	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	—
14	1	1	....	....	....	....	....	1	1	....	....	....	....	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	6
15	....	....	2	1	3	5	3	4	3	1	4	1	3	1	....	....	2	6	....	1	2	1	1	1	1	1	1	2	50
16	1	2	....	3	3	3	4	1	4	1	4	2	3	....	7	2	3	3	5	6	2	2	4	2	1	1	3	1	73
17	3	2	1	1	1	2	3	3	2	6	2	4	4	5	2	6	5	1	3	3	3	5	3	2	7	....	3	6	88
18	....	....	....	2	2	....	....	1	....	2	....	3	....	3	....	2	....	....	2	1	1	2	2	....	....	....	....	....	23
19	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2	....	....	....	....	....	1	1	4
20	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1
Averages	15.3	15.2	15.3	17.0	16.2	15.7	16.0	15.9	15.7	16.9	15.8	16.9	16.1	16.8	17.0	17.0	16.3	15.5	16.7	16.4	16.9	16.8	16.6	16.2	16.7	15.5	16.5	16.7	247

$[o] = 16.5$ $a = 16.5$

$[ot] = +2.19$ $b = +0.009$

$[t] = 23$ $t = 48$

$[t^2] = 205.29$

TABLES 5, 6, and 7 present data for the same wild white-flowered plant (*A*) for three successive years (1913, 1914, and 1915). The age of this plant when transplanted in 1911 from Wisconsin to the experimental garden was unknown. There has been no very marked difference in its general vigor and habit of growth in the five years that it has been under observation, except that in 1914 part of the roots which were inadvertently somewhat exposed were killed by winter freezing and there were fewer main branches produced from the cluster of roots.

The performance of this plant (*A*) in each of the three successive years shows a seasonal decrease that is quite characteristic of the species. There is also rather close agreement in the ranges of partial variability, these being 21–13, 22–15, 22–12. The average number per head and the standard deviation are also quite uniform as follows: 1913, 17.2±1.79; 1914, 17.8±1.41; 1915, 17.3±1.72. There is also rather close agreement in the values for the first date of blooming (*a*), but there was a considerable increase in the length of the flowering period, (*t*) in 1915 over that of the previous years. The rate of decrease (*b*) was lowest in 1915. The significance of these facts and the means of proper comparison of such data will be discussed presently.

The principal interannual partial variability is seen in the length of the blooming period. When this is considerably shorter, as in the year 1914, and the total amont of decrease remains much the same, the rate of decrease (*b*) is necessarily more marked.

The wild white-flowered plant considered above was grown from roots obtained in the field and its growth and vigor were much more uniform in successive years than is the growth of plants grown from seed. The latter, as a rule, exhibit in the second year of growth a marked increase in general vigor as measured by the number and size of the main stems,which gives a corresponding extension of the flowering period with the production of more flowers.

These aspects of interannual partial variability may be illustrated by TABLES 8, 9, and 10, which present the data collected from a plant in the first, second, and third year of growth.

The records of this plant in the first, second, and third years of growth agree in giving lower numbers per head as the

TABLE 5

SEASONAL DISTRIBUTION OF FLOWER NUMBER PER HEAD FOR A WILD WHITE-FLOWERED PLANT (*A*). DATA FOR 1913

Number of flowers per head	June		July												August											September		Total
	27	30	2	5	7	8	10	12	15	17	21	26	28	30	1	4	6	11	15	18	20	23	26	28	30	2	11	
13	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	1	....	....	....	....	2
14	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	1	2	1	1	....	4	4	1	2	....	....	17
15	....	....	....	....	....	....	....	....	....	....	1	1	....	....	....	1	1	1	3	5	6	3	5	5	5	5	....	42
16	....	....	....	1	1	....	2	....	1	2	2	4	....	2	2	1	3	3	2	3	3	3	....	2	2	4	....	43
17	....	....	1	2	1	....	1	1	2	1	2	1	....	5	4	4	3	2	4	1	2	....	1	3	....	1	3	45
18	....	....	1	5	4	1	4	5	3	5	2	3	....	2	3	2	1	1	....	....	....	....	....	....	....	....	1	43
19	1	2	7	2	5	6	3	4	4	1	4	1	1	1	1	....	....	1	....	1	....	....	....	....	....	....	....	45
20	6	1	....	....	....	5	....	1	....	1	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	15
21	....	....	3	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4
Averages.....	19.9	19.3	19.3	17.8	18.2	19.5	17.8	18.5	18.4	17.8	17.5	17.2	19.0	17.2	17.3	16.2	16.2	16.2	15.9	15.7	15.6	14.9	14.5	15.6	15.0	15.6	17.2	256

$[o] = 17.2$ $a = 19.2$

$[ot] = -28.61$ $b = -0.059$

$[t] = 34$ $t = 76$

$t^2] = 481.22$

TABLE 6

SEASONAL DISTRIBUTION OF FLOWER NUMBER PER HEAD FOR A WILD WHITE-FLOWERED PLANT (*A*). DATA FOR 1914

Number of flowers per head	July					August										September			Total
	18	20	22	27	30	3	5	7	11	15	19	21	25	26	28	2	4	10	
15	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	2	1	1	1	2	1	9
16	.....	.....	.....	.....	1	.....	.....	2	.....	1	1	1	.....	2	1	2	1	.....	12
17	.....	.....	1	1	.....	1	.....	1	4	4	4	4	4	4	1	2	2	.....	33
18	1	1	4	1	1	5	.....	3	3	2	5	3	3	2	5	1	.....	.....	40
19	.....	5	4	6	5	2	7	4	4	3	.....	1	1	1	.....	.....	.....	.....	43
20	.....	3	.....	2	3	2	2	.....	.....	.....	.....	.....	.....	1	.....	.....	1	.....	14
21	.....	1	1	.....	.....	.....	1	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	4
22	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1
Averages..........	18.0	19.4	19.0	18.9	18.9	18.5	19.4	18.2	18.0	17.7	17.4	17.2	17.1	17.3	17.3	16.5	16.7	15.0	156

$[o] = 17.8$ $a = 19.3$

$[ot] = -15.67$ $b = -0.059$

$[t] = 25$ $t = 54$

$[t^2] = 263.72$

TABLE 7

SEASONAL DISTRIBUTION OF FLOWER NUMBER PER HEAD FOR A WILD WHITE-FLOWERED PLANT (*A*). DATA FOR 1915

Number of flowers per head	July								August										September							October								Nov.	Total
	8	12	15	17	20	23	26	30	2	5	9	13	16	19	20	24	27	31	2	4	8	18	23	25	28	4	7	11	14	18	21	25	28	4	
12	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
13	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
14	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	1	...	...	...	...	1	...	3
15	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	3	...	...	...	...	1	...	1	...	...	...	1	...	3	2	3	2	1	18
16	...	...	1	...	1	...	...	...	1	1	...	1	3	...	...	2	3	2	...	...	1	1	1	1	1	...	1	1	...	...	1	...	1	...	24
17	...	2	2	3	1	1	...	3	2	...	1	3	4	...	1	4	2	2	...	1	3	1	1	1	2	...	1	1	...	...	...	...	2	1	45
18	...	1	...	2	...	2	1	...	2	2	4	6	...	1	...	2	2	...	...	...	1	...	...	...	...	1	...	1	1	...	...	...	...	...	29
19	...	1	3	2	8	4	4	6	4	1	3	...	2	...	1	...	...	...	...	...	1	...	...	...	...	2	...	...	...	1	...	...	...	...	43
20	1	3	2	2	...	1	4	1	...	3	1	...	...	...	1	1	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	21
21	...	1	2	1	...	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6
22	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
Averages...	20.0	19.0	19.1	18.6	18.5	19.1	19.6	18.5	17.7	18.7	18.4	17.5	17.1	18.0	18.7	17.3	16.3	17.2	14.0	15.0	17.3	16.0	16.5	16.0	16.7	18.7	16.5	16.0	18.0	16.0	15.3	15.0	15.7	16.0	191

$[o] = 17.3$ $\qquad a = 19.0$

$[ot] = -38.60$ $\qquad b = -0.031$

$[t] = 55$ $\qquad t = 119$

$[t^2] = 1234.47$

TABLE 8

SEASONAL DISTRIBUTION OF NUMBER OF FLOWERS PER HEAD FOR FIRST YEAR OF BLOOM OF AN F_1 GENERATION PLANT $(E_3 \times A)$ *no. 7* DERIVED BY CROSSING A PLANT OF BARBE DE CAPUCIN (E_3) AND THE WILD PLANT (A). DATA FOR 1913

Number of flowers per head	August									Total
	6	8	11	14	19	21	26	28	30	
16	.....	.....	.....	.....	.....	.....	.....	.....	1	1
17	.....	.....	.....	.....	2	.....	.....	1	2	5
18	2	3	2	3	3	5	2	6	3	29
19	6	6	4	6	5	5	2	3	1	38
20	2	1	3	2	.....	.....	.....	.....	.....	8
21	.....	.....	1	.....	.....	1	.....	.....	.....	2
Averages..........	19.0	18.8	19.3	18.9	18.3	18.7	18.5	18.2	17.6	83

$[o] = 18.6 \qquad a = 19.1$
$[ot] = -3.17 \qquad b = -0.045$
$[t] = 12 \qquad t = 24$
$[t^2] = 69.89$

season advanced. The range of intraseasonal partial variability was slightly increased in successive years, but there are very marked differences in the length of the blooming period, in the total number of flowers produced, and in the rate of decrease. The length of blooming period in the first year of bloom for this plant was rather below that of the average one-year-old plant. The average number of flowers per head for 1913 is 18.6, for 1914 it is 19.0, and for 1915 it is 18.7. The values of the first date of bloom are 19.1, 20.9, and 19.9. Aside from the rate of decrease the various values are not widely different. In this respect the plant in question is one of the most uniform that we have studied, exhibiting, perhaps, the least interannual variability with respect to values $[o]$ and a.

The interannual partial variability was usually more pronounced than in the plant noted above. Frequently the annual performance was quite divergent in nearly all respects. One of the most marked of such cases is seen in the plant for which data are given in TABLES 11, 12, and 13.

In the first year of growth (TABLE 11), this plant exhibited a rather short period of bloom, the number of flower heads produced was low; the range was only 20–17. In the second year (TABLE 12), the period of bloom was much extended, the total production

TABLE 9

Seasonal distribution of number of flowers per head for the second year of bloom (1914) for the plant ($E_3 \times A$) *no. 7*. Data for first year of bloom given in table 8

Number of flowers per head	July					August											September											Total
	18	20	23	29	31	3	5	7	10	13	15	18	20	24	26	28	1	4	8	10	12	14	16	19	21	24	26	
14	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	1
15	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	1	....	1	3
16	....	....	....	....	....	....	....	....	1	....	....	1	1	....	....	....	....	1	....	....	1	....	1	....	1	....	2	9
17	....	....	....	....	....	....	....	....	....	....	....	3	2	2	1	1	1	2	....	....	1	1	....	....	....	2	1	17
18	....	....	....	....	....	....	....	....	2	1	5	1	1	2	4	7	2	3	1	....	....	1	1	....	1	....	....	32
19	....	....	1	3	2	3	1	6	3	3	1	3	3	3	1	2	1	1	....	1	1	2	....	....	....	....	....	41
20	1	....	3	6	2	3	3	4	3	6	2	2	3	3	1	1	1	2	....	....	....	....	....	1	....	1	....	48
21	2	3	4	1	6	3	6	1	....	....	2	....	1	....	2	....	2	1	1	....	....	....	....	....	....	....	....	35
22	1	3	1	....	....	1	1	....	....	....	1	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	9
23	....	1	1	....	....	....	....	....	....	....	....	....	....	....	....	..	....	....	....	....	....	....	....	....	....	....	....	2
24	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1
Averages.....	21.6	21.7	20.8	19.8	20.4	20.2	20.6	19.5	18.8	19.5	19.4	18.2	18.7	18.7	19.2	18.3	19.1	18.1	17.7	19.0	17.3	18.3	17.0	20.0	16.3	18.0	16.0	198

$[o] = 19.0$ $\qquad a = 20.9$

$[ot] = -23.79$ $\qquad b = -0.053$

$[t] = 36$ $\qquad t = 70$

$[t^2] = 443.11$

TABLE 10

Seasonal distribution of number of flowers per head for the third year of bloom (1915) for the plant ($E_3 \times A$) *no. 7.* Data for first and second years of bloom given in the two preceding tables

Numbers of flowers per head	July										August										September									October								November				Total
	2	6	9	12	15	19	21	23	28	6z	2	6	10	13	17	19	20	24	27	31	2	4	8	11	15	18	23	25	28	4	7	11	14	18	21	25	28	1	4	8	11	
13	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
14	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	2	..	..	..	..	..	..	..	..	..	1	..	..	..	..	5
15	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	1	2	..	..	..	..	..	..	..	..	1	..	..	..	2	..	..	8
16	..	..	..	..	..	..	1	..	..	..	..	1	..	..	..	1	..	..	1	1	1	2	1	1	3	1	1	5	..	1	..	2	..	..	..	..	1	..	1	..	..	25
17	..	..	..	..	1	..	..	1	..	..	..	1	1	2	1	..	2	1	3	4	3	3	2	3	2	1	1	1	1	3	2	..	3	..	..	..	2	..	..	..	..	44
18	..	..	1	..	..	1	1	1	2	1	1	..	2	3	2	1	..	1	2	2	2	3	3	3	..	5	3	1	3	1	..	..	3	4	4	1	1	1	..	1	..	60
19	1	..	..	3	1	3	5	2	3	3	4	5	1	3	3	..	1	5	4	3	2	1	1	..	2	1	3	2	6	1	1	2	2	2	3	1	1	1	2	2	..	86
20	..	..	2	4	4	2	1	1	4	3	5	2	3	..	4	1	1	3	..	..	2	1	2	1	..	..	..	1	..	..	1	2	2	1	2	4	..	..	..	..	1	60
21	..	1	..	3	1	4	1	3	1	2	..	1	3	1	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	1	..	24
22	..	3	6	..	1	..	..	2	..	1	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	14
23	..	2	1	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4
24	..	3	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4
25	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
Averages..	19.0	23.0	21.3	20.0	20.6	19.9	18.4	20.0	19.4	19.9	19.4	18.9	19.5	18.8	19.0	18.0	18.2	19.0	17.9	17.7	18.1	17.6	17.3	17.6	16.6	17.2	17.2	17.3	18.5	17.8	18.2	18.3	18.3	18.6	18.4	19.5	16.8	18.5	16.8	19.2	20.0	336

$[o] = 18.7$ $a = 19.9$

$[ot] = -25.65$ $b = -0.018$

$[t] = 64$ $t = 131$

$[t^2] = 1493.19$

TABLE 11

SEASONAL DISTRIBUTION OF NUMBER OF FLOWERS PER HEAD FOR THE FIRST YEAR OF BLOOM OF AN F_1 GENERATION PLANT ($C \times E_{22}$) *no. 1* DERIVED BY CROSSING A WILD PLANT (C) AND A PLANT OF BARBE DE CAPUCIN (E_{22}). DATA FOR 1913

Number of flowers per head	August									September			Total
	7	8	13	14	16	19	25	27	30	13	23	29	
17	....	....	....	....	....	2	....	1	....	2	1	....	6
18	1	....	2	1	1	2	....	3	....	1	....	1	12
19	1	4	3	2	4	5	8	4	5	7	7	....	50
20	3	2	1	4	3	1	2	2	4	....	....	....	22
Averages........	19.4	19.3	18.8	19.4	19.3	18.5	19.2	18.7	19.4	18.5	18.7	18.0	90

$[o] = 18.9$ $a = 19.2$
$[ot] = -5.00$ $b = -0.016$
$[t] = 19$ $t = 53$
$[t^2] = 285.75$

of heads greatly increased, the range of flowers per head was 22–13, and there was a rather uniform and gradual rate of decrease. For the third year of bloom (TABLE 13), the period of bloom and range of partial variability were quite as in the previous year, but there were irregularities in the decrease in that the lowest numbers per head were reached in the latter part of September followed by a rather decided increase in number per head. For the successive years the numbers for average flowers per head [*o*] are 18.9, 18.3, and 17.9; the values for the first day of bloom (*a*) are 19.2, 21.8, and 18.5, and the values for rate of decrease are −0.016, −0.068, and −0.028. Both the average number per head [*o*] and the value for the first day of bloom (*a*) are decidedly lower in the third year.

The interannual variation in regard to the intraseasonal variabilities was marked in the case of a plant for which data are presented in TABLES 14 and 15, and which have already been referred to as unusual types of interseasonal performance. Here the behavior in the first and second years of growth involve marked differences in the decrease and range. In the first year the daily range and average remained quite the same, in the second year there was a decided decrease in average, but the decrease in range was seen only in the higher number. The values of the number for first day of blooming, 15.3 and 17.1, are widely different, as are the rates of decrease +0.001 and −0.054. However, the averages for flower number per head are quite identical, 15.3 and 15.8.

TABLE 12

SEASONAL DISTRIBUTION OF NUMBER OF FLOWERS PER HEAD FOR THE SECOND YEAR OF BLOOM (1914) FOR THE PLANT ($C \times E_{22}$) *no. 1.* DATA FOR FIRST YEAR GIVEN IN TABLE 11

Number of flowers per head	July						August										September												October										Total
	17	20	23	26	30	31	4	6	8	13	15	18	22	26	28	29	5	7	8	10	12	14	16	19	22	24	26	29	1	3	5	7	9	13	15	20	22	27	
13	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	...	...	...	...	...	...	...	...	...	1	...	...	1	...	2
14	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	...	...	...	...	...	...	...	...	...	...	...	1	...	1	3
15	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	1	1	1	...	1	1	2	1	3	1	1	1	1	...	16
16	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3	..	..	2	..	..	..	...	2	3	3	...	1	1	...	2	5	1	...	...	...	23
17	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	..	..	3	1	3	1	3	1	4	3	...	4	1	1	3	1	2	...	...	...	...	...	...	33
18	..	..	..	..	..	..	..	..	..	..	1	1	..	..	..	..	2	2	3	..	1	2	2	1	3	4	1	2	...	1	...	...	...	...	...	...	...	...	26
19	..	..	..	2	2	..	1	..	..	5	1	8	8	4	5	3	12	5	4	6	5	4	1	4	3	2	1	2	2	1	...	...	1	...	...	...	...	...	92
20	..	1	..	3	2	3	3	4	2	2	3	4	2	5	2	4	2	1	2	1	1	1	1	1	...	1	...	...	...	...	...	...	...	...	...	...	...	...	51
21	2	4	5	5	8	1	6	6	7	3	1	1	..	..	1	3	1	..	..	..	..	..	..	..	...	...	...	...	...	...	...	...	...	...	...	...	...	...	54
22	..	5	4	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	...	...	...	...	...	...	...	...	...	...	...	...	...	...	10
Averages....	21.0	21.4	21.2	20.3	20.5	20.6	20.5	20.6	20.8	19.8	19.7	19.3	19.2	19.1	19.0	20.0	19.1	17.9	18.7	18.5	18.2	18.3	18.4	18.2	17.7	17.7	16.8	17.4	17.5	17.0	15.4	16.3	16.0	15.4	15.5	14.5	14.0	14.0	310

$[o] = 18.3$ $a = 21.8$

$[ot] = -57.08$ $b = -0.068$

$[t] = 52$ $t = 102$

$[t^2] = 842.00$

TABLE 13

SEASONAL DISTRIBUTION OF NUMBER OF FLOWERS PER HEAD FOR THE THIRD YEAR OF BLOOM (1915) FOR THE PLANT ($C \times E_{22}$) *no. 1*. DATA FOR FIRST AND SECOND YEARS GIVEN IN TWO PRECEDING TABLES

Number of flowers per head	June	July											August									September										October							Total
	29	2	6	9	12	15	17	21	23	26	28	31	5	7	10	13	16	18	21	25	28	1	2	4	8	11	15	18	23	25	28	4	7	11	14	18	21	25	
12	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	1	..	..	..	..	..	..	..	..	8
13	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	4	2	..	..	..	..	..	..	..	..	..	2
14	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	1	2	1	3	2	1	1	1	1	..	1	..	..	..	..	15
15	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	2	1	1	..	..	2	..	3	2	4	3	2	5	1	1	1	..	..	..	29
16	..	..	..	..	..	1	..	2	3	1	1	1	..	1	..	1	2	4	3	1	2	2	3	3	4	3	..	2	1	4	5	1	1	4	1	2	3	2	64
17	..	..	1	..	3	2	..	3	5	3	4	8	8	7	6	3	4	3	5	2	4	4	4	5	2	4	2	..	..	..	1	..	..	1	..	2	1	2	99
18	..	1	6	5	7	6	6	5	2	4	4	1	1	2	3	2	1	1	1	1	2	3	2	1	..	1	1	..	..	..	1	..	..	..	..	1	..	1	72
19	..	..	3	5	..	1	4	..	..	2	1	1	1	..	1	3	1	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	1	..	..	1	..	..	26
20	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2
21	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4
22	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
Averages..	21.0	19.0	18.2	18.5	17.7	17.7	18.4	17.3	16.9	17.7	17.5	17.2	17.3	17.1	17.5	18.1	18.0	16.2	16.8	16.6	17.0	16.9	17.2	16.5	15.3	16.1	15.2	14.2	14.6	15.0	15.9	15.0	16.7	15.7	15.5	17.2	16.2	16.8	322

$[o] = 17.9$ $a = 18.5$

$[ot] = -33.46$ $b = -0.028$

$[t] = 56$ $t = 118$

$[t^2] = 1226.37$

TABLE 14

SEASONAL DISTRIBUTION OF NUMBER OF FLOWERS PER HEAD FOR THE FIRST YEAR OF BLOOM OF AN F_2 GENERATION PLANT ($E_{22} \times A$)–*10–no. 17* DERIVED FROM A CROSS BETWEEN A PLANT OF BARBE DE CAPUCIN (E_{22}) AND A WILD PLANT (A). DATA FOR 1915

Number of flowers per head	September														October												November			Total
	14	15	16	17	18	20	22	23	24	25	27	28	29	30	1	4	6	7	8	9	11	13	16	19	22	26	1	4	8	
12	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
13	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	1	...	...	...	...	...	1	1	...	...	...	...	4
14	1	...	3	4	4	2	1	...	2	1	1	1	1	...	1	...	1	2	...	...	1	1	...	...	...	...	...	...	2	29
15	6	8	3	2	2	3	3	4	4	4	6	6	5	6	8	5	5	5	5	5	4	5	9	1	4	1	3	...	2	124
16	2	2	3	4	4	2	3	4	2	4	...	2	2	4	1	2	1	2	...	3	2	3	1	4	...	2	...	1	1	61
17	...	...	...	...	...	2	3	2	2	1	1	...	2	...	...	3	...	...	...	...	...	1	...	1	...	...	...	...	...	18
18	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	2
Averages	15.1	15.2	14.7	15.0	15.0	15.4	15.8	15.8	15.4	15.5	14.9	15.4	15.5	15.4	15.0	15.8	15.0	14.8	15.0	15.7	15.1	15.4	15.1	15.4	14.6	15.7	15.0	16.0	14.8	239

$[o] = 15.3$ $\qquad a = 15.3$

$[ot] = +0.22$ $\qquad b = +0.001$

$[t] = 23$ $\qquad t = 52$

$[t^2] = 236.72$

TABLE 15

SEASONAL DISTRIBUTION OF NUMBER OF FLOWERS PER HEAD FOR THE SECOND YEAR OF BLOOM (1916) FOR THE PLANT ($E_{22} \times A$)-*10-no. 17*. DATA FOR FIRST YEAR GIVEN IN TABLE 14

Number of flowers per head	July										August								Total
	5	7	10	13	15	18	21	24	27	29	1	4	7	11	15	18	25	28	
14	...	...	...	...	...	...	...	...	...	...	1	1	1	1	...	1	1	1	7
15	2	...	4	...	1	4	5	1	6	4	6	5	6	3	4	6	...	1	58
16	1	5	1	1	2	3	3	5	2	4	3	2	1	3	1	...	...	...	37
17	3	2	4	6	4	3	2	3	2	2	..	2	2	1	...	...	...	...	36
18	1	...	1	3	2	...	...	1	...	...	...	...	...	...	...	...	...	...	8
19	1	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3
20	1	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2
21	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
Averages	17.5	17.2	16.2	17.2	16.8	15.9	15.7	16.4	15.6	15.8	15.2	15.5	15.4	15.5	15.2	14.9	14.0	14.5	152

$[o] = 15.8$ $a = 17.1$
$[ot] = -13.90$ $b = -0.054$
$[t] = 24$ $t = 54$
$[t^2] = 261.11$

2. INDIVIDUAL VARIABILITY

The various types of intraseasonal variability noted above are in reality records of the performance of individual plants during a seasonal period of growth. The differences noted between them as individuals are, therefore, evidences of individual variability. Individuals may differ decidedly in respect to one or more values, total production of heads, average and range of number of flowers per head, or amount and rate of decrease. These differences may appear among plants of the same age.

The interannual variability and especially that seen in the first two years of growth indicates clearly that much individual variability may exist in plants of different ages.

The inter-relations of individual variability and partial variability are here very evident. Any estimate of the former involves the latter in one or in all its aspects. It seems, therefore, clear that the question of an adequate judgment of the individual must be based on full performance at least during one season of growth, and that the comparison of individuals should be made for plants of the same age.

II. STATISTICAL TREATMENT OF DATA

The various sources of partial variability considered above make clear some essentials in regard to the proper collection and utilization of data in order that they may reveal the nature of the character of flower number and its hereditary behavior. If the flower number per head fluctuated with much the same range from day to day, as it does for a few plants of chicory, the mean, the standard deviation, and the coefficient of variability would be quite sufficient to give an estimate of the individual and could be determined from rather random readings with the magnitude of error depending chiefly on the number of heads that were counted. But this is not the case with the majority of plants. The flower heads mature at different dates and the number per head, as a rule, decreases as the season advances. It will be shown later this is to some degree related to the position of the head on a plant.

The partial variations from day to day are not solely fluctuating. For most plants, as shown in TABLES 1, 2, and 41 the daily range of fluctuation changes in a somewhat uniform progression to lower values. It seems to the writers that this element of change should be recognized in any statistical treatment which attempts adequately to determine values for a plant as a whole.

In this investigation, instead of calculating the mean and the variability, as expressed either by the standard deviation or the coefficient of variability, and using these as expressions to characterize the flower number of an individual plant, the *flower number of the first day of bloom* and the *rate of change* have been calculated and used.

The latter expression, as will be seen more clearly presently, is calculated as the mean and the variability would be from all the data at hand. A starting point, a rate of change, and the length of time through which this change takes place, gives an index to the variability. Furthermore, one can find the average flower number for any one particular day (o_n for t_n), if the flower number is given for the first day of bloom and the rate of change following (either positive or negative). We may assume, for the present, that the rate of change is uniform and call it b, and we shall indicate the flower number for the first day of bloom (which is to be calculated) a.

It is obvious from such typical data as have been presented in the foregoing tables that the average flower number for any particular day (o_n for t_n, for example) involves the actual flower number on the first day of bloom plus the amount of change, either positive or negative, following that date. In respect to flower number in chicory the change is usually a decrease, and if this decrease be computed it can be expressed as a rate of change for the season and designated as the value b. The amount of change from the first day of bloom to any one particular day (after the plant has been in bloom t_n days for example) can be expressed by the number of days the plant has been in flower multiplied by the rate of change, as bt_n. According to this conception then $o_n = a + bt_n$, and the following series of linear equations will express the series of averages obtained from the actual observations day by day: $o_0 = a + bt_0 \ . \ . \ . \ o_n = a + bt_n$.

From the data the average of the flower number obtained from day to day can readily be determined. This value for the data collected for the plant E_3 (see TABLE 1) arranged in the first column of TABLE 16 is 18.6.

The values of t are also known and can be expressed as deviations from the average time of blooming computed from the known dates of the collection of data. This average as given for plant E_3 in the second column of TABLE 16 is 30.7. Since this average is often a fraction the calculation may be simplified by measuring the different times of the collection of data from the integer nearest to the average so that $t_n = t + \tau_n$ when t is the integer nearest the average and τ_n is the deviation of t_n from this integer. If the difference between the true average and the integer used in the calculation be considered as d then the full value for the deviation from the true average is $\tau_n + d$.

The average of all the $(\tau + d)$'s must, of course, equal zero, because they express the plus and minus deviations from the true average. The average of all the τ's equals $-d$. The equations then assume the form:

$$o_0 = a + b\,(t + d + \tau_0)$$
$$o_1 = a + b\,(t + d + \tau_1)$$
$$o_2 = a + b\,(t + d + \tau_2)$$

. . . .

. . . .

. . . .

$o_n = a + b\,(t + d + \tau_n)$

The average of this series is 1 $[o] = a + b\,[t]$; because as shown above $[\tau] = -\,d$ and $+\,d - d = o$.

The value of a thus becomes equal to $[o] - b\,[t]$ and of these quantities $[o]$ and $[t]$ are determined from the data and are known.

For the purpose of calculating the value of b another equation is needed and this may be obtained by multiplying each of the above series of equations by $\tau + d$. Since, however, d is the same value throughout we may ignore it and we have:

$o_0\,\tau_0 = \{a + b\,(t + d)\}\tau_0 + b\tau_0^2$

$o_n\,\tau_n = \{a + b\,(t + d)\}\tau_n + b\tau_n^2$

Averaging and substituting $[\tau] = -d$,

2 $[o\tau] = -\,d\,(a + bt) - bd^2 + b\,[\tau^2]$

3 $[o]\,d = d\,(a + bt)$ Multiplying 1 by d gives 3

4 $[o\tau] + d\,[o] = b\,[\tau^2] - bd^2$ Adding 2 and 3 gives 4

Solving this equation the value of b is obtained, and substituting the value of b in 1 gives the value of a.

In TABLE 16 are calculated the values of b and a for the plant E_3 in 1913 (see TABLE 1 for values of o) in order to illustrate the method employed.

It will be more apparent in the presentation of data that follows that differences in the rate of decrease throughout the season already noted in the general survey of intraseasonal partial variability are undoubtedly the source of greatest individual variability. The expression $[o] = a + b\,[t]$ as developed above can be used to express the general behavior of an individual in respect to flower number, and from it are determined the values of a and b to be used in comparisons.

The values of a and b therefore may be discussed further. In the plant involved in TABLE 16 the value of b is -0.065. This is the value of the amount of decrease per day estimated from all the observations. While the actual variation in the rate is more or less variable in the data as collected, there is much in the behavior to suggest that until more of the factors contributing to this are known and analyzed, it may be treated theoretically as a uniform rate in each plant, an assumption which will admit of the foregoing mathematical treatment.

TABLE 16

CALCULATION OF FLOWER NUMBER OF FIRST DAY OF BLOOM (a) AND SEASONAL RATE OF DECREASE (b) FROM THE DATA FOR A PLANT OF BARBE DE CAPUCIN (E_3) PRESENTED IN TABLE 1

o	t	$\tau + d$	$o(\tau + d)$	$(d + \tau)^2$
+ 3.4	0	− 31	− 1054	961
2.5	1	30	750	900
2.5	2	29	725	841
2.7	5	26	702	676
1.9	7	24	456	576
1.5	11	20	300	400
1.9	13	18	342	324
0.7	15	16	112	256
1.5	18	13	195	169
1.4	20	11	154	121
1.6	23	8	128	64
1.1	25	6	66	36
3.0	26	5	150	25
0.8	28	3	24	9
0.3	30	1	3	1
− 0.7	33	+ 2	14	4
0.8	35	4	+ 32	16
0.4	37	6	24	36
1.6	40	9	144	81
1.0	44	13	130	169
1.0	47	16	160	256
1.0	50	19	190	361
1.4	55	24	336	576
0.8	60	29	232	849
1.4	64	33	462	1089
1.5	67	36	540	1296
1.4	74	43	602	1849
[o] 18.0 + 0.6	30.7		[ot] = − 29.49	[t^2] = 441.96
	[$\tau + d$] = 31 − 0.3			

Substituting in formula derived above

(1) $+ 0.6 = a + 31b$

(2) $- 29.49 = + 0.3(a + 31b) + 441.96b - (0.09b^2)$ (last value so small that it may be neglected)

(3) $+ 0.18 = + 0.3(a + 31b)$

(4) $- 29.67 + 441.96b$

$\therefore\ b = - 0.065$

$a = 18.0 + 2.6 = 20.6$

The question will immediately arise whether the assumption of a uniform rate of decrease is justified. If there were only meager data at hand for each plant it would be necessary to use the mean and the standard deviation as values. In such cases it would be recognized that such values are not the most satisfactory expression of flower number, but that they are the best available from the material at one's disposal. In chicory, however, there are sufficient data to enable the determination of a more adequate expression for the behavior with respect to flower number; namely, the theoretical value for the first day of bloom (*a*) and the rate of decrease per day (*b*).

It is, however, evident that the rate of decrease is influenced by a large number of factors such as length of blooming period, position of heads on branches, kinds of heads, whether terminal or lateral, etc., points which will be brought out later in the paper, and that it is in consequence not uniform throughout the season. The data, while sufficient to give us an approximate value for the rate of decrease, are not sufficient to determine it absolutely, and it must be borne in mind that the expression for flower number used in this paper is not considered to be absolute, but merely the most adequate to be obtained from the material at hand. This value can be determined from all the data in the manner developed above.

The value of *a* can also readily be determined on the basis of the observations. In the case of the data in TABLE 16, $a = 18.6 - [(-0.065)\ 31] = 20.6$. This is a computed value for the flower number of the first date of bloom.

It will be seen that two plants which start with the same flower number per head and show the same rate of decrease must have a different average number of flowers per head for the whole season if their blooming periods are of different lengths. The average will be lower the longer the blooming period. Just so the standard deviation will be the greater the longer the blooming period. On the other hand, if the two plants show differences in the rate of decrease the average number of flowers per head for the whole season may be the same in the two plants. The following comparison should make the point quite clear. The plant E_3 (TABLES 1 and 2) bloomed 74 days in 1913 with an average flower number for the season of 18.6 and a standard deviation ± 1.9. In 1914 it bloomed 91 days with an average flower number of 19.2 and standard deviation of ± 1.5. Does this mean that in 1914 E_3 started with a higher number of flowers per head than in 1913, and maintained this characteristic throughout the season, or was the starting point in the two years the same with a difference in the manner of decrease? In using the method described above, for the plant E_3 for the year 1913, the number of flowers per head for the first day of bloom was 20.6 with a decrease of -0.064 per day; while for the year 1914 the average number of flowers for the first day of bloom was 20.7 with a rate of decrease of -0.032. The higher average in 1914 was due to a slower rate of decrease. To illustrate this point further we may take the plant $(E_3 \times A)$ *no.* 7 (TABLES 8 and 9) in 1913 and 1914. In 1913 the average was 18.6 with a standard deviation of ± 0.9; in 1914, 19.0 with a standard deviation of ± 1.7. In 1913 the blooming period was 24 days; in 1914, 70 days. The averages are the same as for the plant E_3, but the standard deviation is smaller for $(E_3 \times A)$ *no.* 7 in 1913. The values for the first day of bloom and the rate of decrease show that the plants are different in respect to flower number. In the plant $(E_3 \times A)$ *no.* 7 the difference between the rate of change in 1913 and 1914 is not very great. In 1913 it was -0.045; in 1914, -0.053. The average flower number for the first day of bloom is, however, quite different for the two years. In 1913 it was 19.1; in 1914, 20.9. This together with the different length of blooming periods accounts for the differences in the values of a obtained for the plants E_3 and $(E_3 \times A)$ *no.* 7.

III. DETAILED PRESENTATION OF DATA BEARING ON

1. RELATION OF LENGTH OF BLOOMING PERIOD TO RATE OF CHANGE

One of the most obvious facts brought out by the data is that in plants showing a seasonal decrease the rate of decrease is less the longer the blooming period. The following correlation table (TABLE 17) brings out this fact very clearly. The plants used are three-year-old F_1 plants, of which there are data for 110 plants.

For a further study of the relation of rate of decrease to length of flowering period these plants may be grouped as indicated. As there were rather few plants with short blooming periods, it was necessary to include in the first group all the plants that bloomed less than 60 to 100 days. This group consisted of 16 plants. There were only three plants that bloomed less than 60 days, so these were left out entirely. In order to have a sufficient number of plants in the fifth group those blooming from 130 to 150 days were here included.

The table shows that there is a considerable negative correlation between length of blooming period and rate of decrease. The high values for the rate of decrease all fall in the first group, that is the group containing the plants with the shortest blooming periods. The fifth group, which is the group of plants with the longest blooming period, has the lowest values for the rate of decrease.

TABLE 17

CORRELATION BETWEEN LENGTH OF BLOOMING PERIOD AND RATE OF DECREASE. DATA FOR 110 F_1 PLANTS, 3 YEARS OLD

Days of bloom	Rate of decrease in units (×100)											Total	
	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11		
40–50	....	....	....	....	....	....	1	....	....	....	....	1	......
50–60	....	1	1	....	....	....	....	....	....	....	....	2	......
60–70	....	....	....	....	....	....	1	....	....	....	....	1	1
70–80	....	....	....	1	1	....	....	....	....	....	1	3	
80–90	....	....	....	1	1	2	....	1	....	1	....	6	
90–100	1	....	....	....	1	1	....	1	1	1	....	6	
100–110	....	2	1	5	1	5	1	....	....	....	....	15	2
110–120	1	5	7	8	4	1	....	....	....	....	....	26	3
120–130	1	7	8	9	4	3	....	....	....	....	....	32	4
130–140	....	2	5	2	1	....	....	....	....	....	....	10	5
140–150	....	2	5	1	....	....	....	....	....	....	....	8	
Total......	3	19	27	27	13	12	3	2	1	2	1	110	

$r = -0.67$

The average flower number was calculated in successive twenty-day periods for each group. TABLE 18 gives the average flower number for these twenty-day periods. The five groups are very much alike, excepting that there is, perhaps, a somewhat greater decrease between the first and second twenty days in the plants

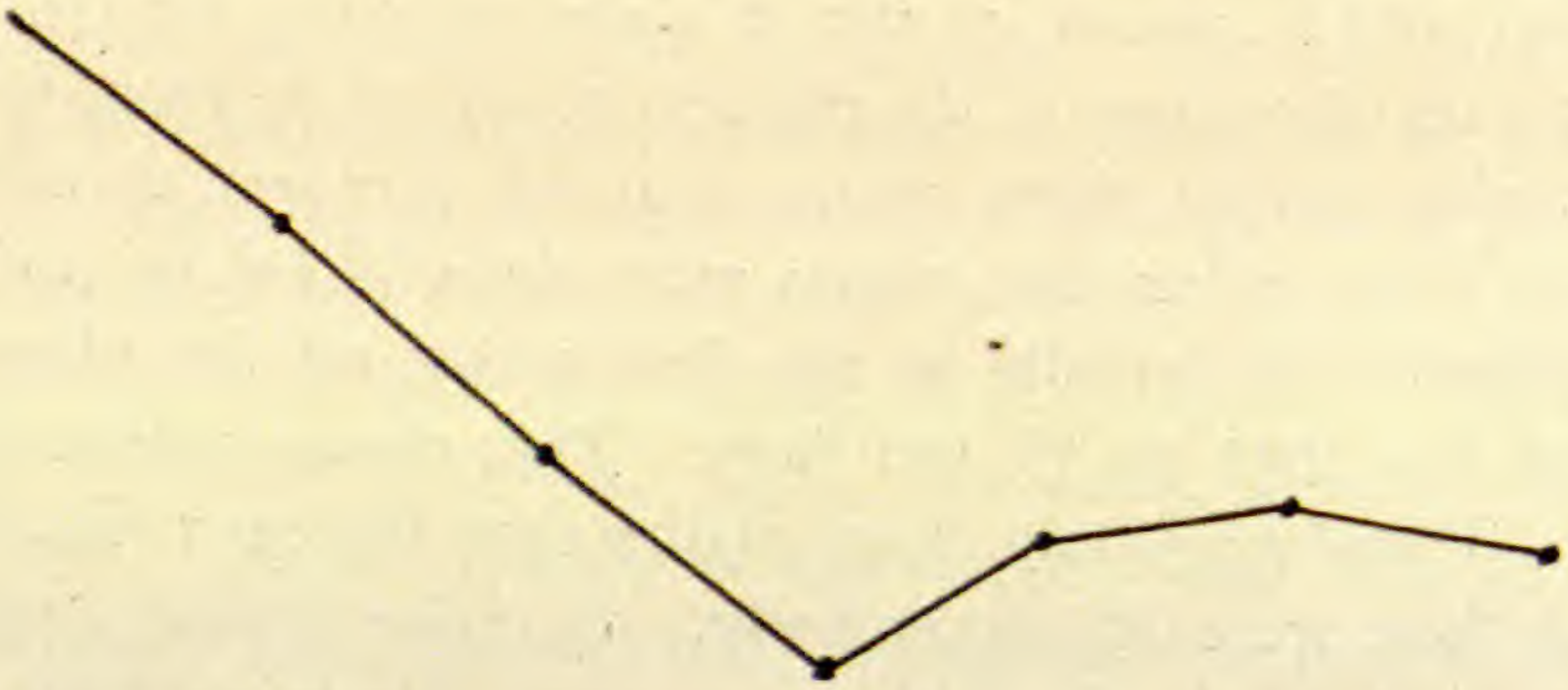


DIAGRAM ACCOMPANYING TABLE 18 SHOWING CURVE FOR AVERAGE DECREASE FOR SUCCESSIVE TWENTY-DAY INTERVALS OF BLOOM.

TABLE 18

AVERAGE FLOWER NUMBER AND AVERAGE VARIABILITY FOR SUCCESSIVE 20-DAY PERIODS OF BLOOM. DATA FOR 110 F_1 PLANTS, 3 YEARS OLD (SAME AS PRESENTED IN TABLE 17)

	1			2			3			4			5			Average difference
	Up to 60 days			Up to 100 days			Up to 110 days			Up to 120 days			Up to 130 days			
	Average	Difference	Number of heads	Average	Difference	Number of heads	Average	Difference	Number of heads	Average	Difference	Number of heads	Average	Difference	Number of heads	
First 20 days....	20.5		2,257	20.3		2,195	19.9		3,608	19.7		4,536	20.3		2,428	......
Second " "	19.5	−1.0	1,178	19.0	−1.3	1,053	19.0	−0.9	2,140	18.9	−0.8	2,678	19.4	−0.9	1,435	−0.94
Third " "	18.2	−1.3	666	18.0	−1.0	717	17.9	−1.1	1,627	17.6	−1.3	1,807	18.7	−0.7	1,010	−1.11
Fourth " "	......	......	......	17.1	−0.9	698	17.0	−0.9	1,209	16.8	−0.8	1,536	17.5	−1.2	1,096	−1.00
Fifth " "	......	......	......	17.8	+0.7	249	17.8	+0.8	849	17.1	+0.3	985	17.6	+0.1	839	+0.43
Sixth " "	......	......	......	......	......	......	17.6*	−0.2	337	16.5	−0.6	867	18.1	+0.5	729	0.00
Seventh" "	......	......	......	......	......	......	......	......	......	......	......	......	17.8*	−0.3	296	−0.30

	σ	Difference	Number of heads	σ	Difference	Number of heads	σ	Difference	Number of heads	σ	Difference	Number of heads	σ	Difference	Number of heads	Average difference
First 20 days....	±1.91		2,257	±1.82		2,195	±1.73		3,608	±1.98		4,536	±2.02		2,428	......
Second " "	±1.51	−0.40	1,178	±1.62	−0.20	1,053	±1.63	−0.10	2,140	±1.57	−0.41	2,678	±1.41	−0.61	1,435	−0.34
Third " "	±1.92	+0.41	666	±2.00	+0.38	717	±1.97	+0.34	1,627	±1.91	+0.34	1,807	±1.92	+0.51	1,010	+0.40
Fourth " "	......	......	......	±2.10	+0.10	698	±2.10	+0.13	1,209	±2.03	+0.12	1,536	±2.14	+0.32	1,096	+0.18
Fifth " "	......	......	......	±1.77	−0.33	249	±2.06	−0.04	849	±1.95	−0.08	985	±1.99	−0.15	839	−0.15
Sixth " "	......	......	......	......	......	......	±2.10*	+0.04	337	±1.74	−0.21	867	±1.80	−0.19	729	−0.12
Seventh" "	......	......	......	......	......	......	......	......	......	......	......	......	±1.65*	−0.15	296	−0.15

* Ten days

with short blooming periods. In the plants with the longest blooming periods, the greatest decrease comes between 40 and 60 days, while in the others it comes between 20 and 40 days. In the last column are given the average differences for the successive twenty-day periods. It will be seen that the greatest difference is between the first and second period, so that here the rate of decrease must be the greatest. Between the third and fourth period there is an increase in flower number rather than a decrease, and after that there is only a slight decrease, if any. The diagram of TABLE 18 illustrates this point. The differences between the averages of the different periods have been plotted and it will be seen that there is a marked change in the rate of decrease after the first eighty days. Plants that bloom eighty days and less will show a greater rate of decrease than those that bloom longer for the reason that there is a slight increase or no further decrease in flower number after the first eighty days. This accounts for the large negative correlation between rate of decrease and length of blooming period. This discussion also illustrates the fact that the range of variability in respect to high and low flower number per head is not very closely related to length of bloom.

The variabilities have also been calculated for the successive twenty-day periods (TABLE 18). The σ's show a decrease, then an increase, and following this they again decrease. Since all the factors influencing flower number are not known, one cannot define the different variabilities exhibited by the different periods. We know, however, that there are sources of variability during the first period which do not exist later on, as, for instance, the coming into bloom of the different branches. The decrease in variability towards the end of the blooming season follows necessarily from the fact that there is a limit to the lowest number of flowers per head produced by a plant. The high numbers which appeared early in the season do not as a rule appear late in the season; the low numbers, however, appear early and do not decrease further as the season advances.

The range of variability for three-year-old F_1 plants and one-year-old F_3 plants for successive twenty-day periods is given in TABLE 19. These plants are reported in detail in TABLES 18 and 20.

TABLE 19

RANGE OF VARIABILITY FOR SUCCESSIVE 20-DAY PERIODS OF BLOOM. DATA FOR F_1 3-YEAR-OLD PLANTS (REPORTED IN TABLE 18). DATA FOR F_3 1-YEAR-OLD PLANTS (REPORTED IN TABLE 20)

		Range of variability	Difference	Number of plants
F_1	First 20 days	30–14	16	107
	Second " "	27–10	17	107
	Third " "	25–12	13	107
	Fourth " "	25–10	15	91
	Fifth " "	23–10	13	76
	Sixth " "	24–11	13	50
	Seventh " "	22–12	10	18
F_3	First 20 days	33–10	23	110
	Second " "	24– 9	15	97
	Third " "	23–11	12	78
	Fourth " "	23–10	13	39
	Fifth " "	20–12	8	12

This table shows that the lowest flower number on a plant may appear in the first or second twenty days of the blooming period while the highest number appears only in the beginning of the season and decreases as the season advances. This must, of course, result in a smaller variability for the end of the season and also explains why there is such a marked negative correlation between rate of decrease and length of the blooming period.

The period of bloom for plants in the first year of growth is shorter than in the succeeding years. There is, however, a similar negative correlation between rate of decrease and length of blooming period, as in the older plants discussed above. For the behavior of plants in the first year of bloom there are data on 110 of the F_3 plants, all blooming in the same year (1915). The plants, for convenience, have been grouped into five groups, each group blooming twenty days longer than the preceding. As shown in TABLE 20 the same sort of differences appear in successive twenty-day periods as in the older plants, that is, the differences are less or there may even be an increase in the later periods.

The variabilities for the F_3 plants are given in the same way as for the F_1 plants, and here too the σ's are the greatest for the first twenty days.

From the foregoing discussion, it is clear that there is less difference between the averages and that the variabilities are lower for twenty-day periods after the first eighty days for the three-

TABLE 20

AVERAGE FLOWER NUMBER AND AVERAGE VARIABILITY FOR SUCCESSIVE 20-DAY PERIODS OF BLOOM. DATA FOR 110 F_3 PLANTS, ONE YEAR OLD

	Up to 20 days			Up to 40 days			Up to 60 days			Up to 80 days			Up to 100 days			Average Difference
	Average	Difference	Number of heads	Average	Difference	Number of heads	Average	Difference	Number of heads	Average	Difference	Number of heads	Average	Difference	Number of heads	
First 20 days......	18.0	......	1,359	17.5		2,457	17.3		5,626	17.8		4,129	18.5		1,860	
Second " "	......	......	......	16.4	−1.1	1,127	16.7	−0.6	2,777	17.1	−0.7	2,201	17.3	−1.2	1,069	−0.90
Third " "	......	......	......	......	......	......	15.9	−0.8	1,249	16.1	−1.0	1,133	16.2	−1.1	680	−0.97
Fourth '	......	......	......	......	......	......	......	......	......	16.1	0.0	656	15.7	−0.5	460	−0.25
Fifth ' "	......	......	......	......	......	......	......	......	......	......	......	......	15.9	+0.2	381	+0.20
	σ	Difference	Number of heads	σ	Difference	Number of heads	σ	Difference	Number of heads	σ	Difference	Number of heads	σ	Difference	Number of heads	Average Difference
First 20 days......	±2.11	......	1,359	±2.08		2,457	±1.84		5,626	±1.83		4,129	±2.02		1,860	
Second " "	......	......	......	±1.71	−0.37	1,127	±1.71	+0.13	2,777	±1.74	−0.09	2,201	±1.73	−0.29	1,069	−0.16
Third " "	......	......	......	......	......	......	±1.66	−0.05	1,249	±1.61	−0.13	1,133	±1.54	−0.19	680	−0.12
Fourth " "	......	......	......	......	......	......	......	......	......	±1.71	+0.10	656	±1.64	−0.10	460	+0.10
Fifth " "	......	......	......	......	......	......	......	......	......	......	......	......	±1.46	−0.18	381	−0.18

DIAGRAM ACCOMPANYING TABLE 20 SHOWING CURVE FOR AVERAGE DECREASE FOR THE FIVE SUCCESSIVE TWENTY-DAY INTERVALS OF BLOOM.

year-old F_1's and after the first sixty days for the one-year-old F_3's. In other words, most of the decrease has taken place during eighty days in the first case and during sixty in the second. It is quite obvious then, when purely mathematically considered, that there should be a large negative correlation between rate of decrease and length of blooming period.

2. SIGNIFICANCE OF THE RANGE OF VARIABILITY IN FLOWER NUMBER PER HEAD

A question which arises in this connection, and which appears to be of considerable biological significance, is whether the total amount of decrease or the actual range in variation in flower number throughout the season bears any relation to the highest flower number in the plant. In other words, do plants with high flower number show a larger total decrease than those with low, or is the amount of decrease about the same in each? The question was suggested by the comparison given above of the data for different periods of bloom, when it became evident that the variability during the later periods was lower than that of the earlier.

The following tables, one for three-year-old F_1 plants and one for one-year-old F_3 plants (the same used above) will perhaps best answer the question. Here the total range from highest to lowest flower number has been recorded, the plants with the same highest

TABLE 21

RANGE OF VARIABILITY OF FLOWER NUMBER PER HEAD OF 106 THREE-YEAR-OLD PLANTS OF THE F_1 GENERATION

Number of plants	Maximum flower number	Minimum flower number		Difference between maximum and average minimum
		Range	Average	
1	30	———	15.0	15.0
2	29	13–12	12.5	16.5
3	28	17–14	15.3	12.7
5	27	15–12	14.2	12.8
14	26	16–12	14.0	12.0
8	25	17–13	14.2	11.8
17	24	15–11	13.8	10.2
19	23	16–10	12.6	10.4
21	22	17–11	12.9	9.1
13	21	16–11	13.2	7.8
3	20	13–11	12.0	8.0

number are put in one group. The highest numbers for the 106 plants of TABLE 21 range from 30 to 20 and the lowest numbers from 16 to 10; for the plants of TABLE 22 the highest numbers range from 33 to 17 and the lowest from 17 to 9. For the plants as a whole there is therefore a greater range for the highest number per head than for the lowest number.

TABLE 22

RANGE OF VARIABILITY OF FLOWER NUMBER PER HEAD OF 189 ONE-YEAR-OLD PLANTS OF THE F_3 GENERATION

Number of plants	Maximum flower number	Minimum flower number		Difference between maximum and average minimum
		Range	Average	
1	33	——	13.0	20.0
1	27	——	13.0	14.0
5	26	15–13	14.4	11.6
3	25	15–14	14.7	10.3
9	24	15–13	13.8	10.2
25	23	16–10	13.6	9.4
41	22	17–10	13.9	8.1
48	21	17–11	13.5	7.5
36	20	15– 9	12.9	7.1
11	19	13–11	12.0	7.0
8	18	14–10	11.9	6.1
1	17	——	11.0	6.0

The plants with highest numbers, however, show the greatest range of variability as their lowest numbers are as low as the majority of the plants with lowest values of the highest number. A glance at the TABLES 21 and 22 shows this point. Of three-year-old plants those with such high numbers as 30–26 have lowest numbers of 17–12, while those with high values at 22–20 range from 17–11. Of the one-year-old plants the ones with high values of 33–23 have low values of 16–10, while those of 22–17 have lowest values, ranging from 17 to 9. The extremes and the averages of the lowest numbers are quite the same irrespective of the higher values.

Different plants exhibit greater variation in respect to the highest number of flowers borne in any head than in regard to the lowest, and therefore an individual plant exhibits the greatest range if the highest number is high for that plant. The variabilities of individuals and of groups increase as the upper limits of flower number increase.

These facts have a special significance in suggesting that any evolutionary change that may have occurred or that may be now in progress in respect to flower number is affecting the high numbers more than the low. The numbers in the various classes, as revealed in TABLES 21, 22, and 23, indicate that there are few plants with extremes of highest flower value and that the greater number of plants of the general population as grown have intermediate values for the highest flower number. In other words, highest flower number exhibits fluctuating variation of greater extent than lowest flower number and is to a large measure independent of the latter. Data will be given later regarding the heredity of high values as expressed for a plant as a whole by values of *a*, and also as to the effect of selection on high or low values.

TABLE 23

RANGE OF VARIABILITY OF FLOWER NUMBER PER HEAD FOR 219 ONE-YEAR-OLD PLANTS OF THE F_4 GENERATION

Number of plants	Maximum flower number	Minimum flower number		Difference between maximum and average minimum
		Range	Average	
1	26	—	12.0	14.0
4	25	16–11	14.0	11.0
2	24	14–13	13.5	10.5
7	23	15–11	13.4	9.6
19	22	16–12	14.1	7.9
45	21	17– 9	13.4	7.6
61	20	15– 7	13.3	6.7
55	19	15–11	12.9	6.1
20	18	13–11	12.3	5.7
5	17	14–12	12.8	4.2

3. RELATION OF FLOWER NUMBER PER HEAD TO POSITION OF HEADS

A. *Descriptive studies regarding position.*

Early in the collection of data, it was observed that the first heads to bloom are, as a rule, situated on the uppermost branches, and also that the first head which opened on a branchlet or in a cluster of flower heads is the terminal one. This at once suggested that the seasonal decrease so uniformly observed may be related to a succession of bloom involving a periodicity between development of different main laterals and also between different secondary branches of main laterals.

As a rule chicory plants are much branched. Grown from seed there is in the first year a single main stem. In the variety "red-leaved Treviso" there is a rather uniform duplication of the single main stem, giving two stem elements usually quite pronounced but cohering strongly.

From the main axis numerous laterals arise which are further branched, producing bushy plants as shown in PLATES 10 and 11. All branches end in flower heads, but considerable variation exists in the development of the ultimate branches, not only for different individual plants but among the different branches of a single plant. In some plants many of the ultimate branches are elongated, giving a divaricate habit with many heads that appear solitary and decidedly terminal (PLATE 12, marked 1). Branches which are lateral to these are usually less elongated (PLATE 12, 2 on plate), so that the flower heads appear sessile, but these in turn may have further lateral but much reduced branches. Very often several branches constituting a system in the axil of a leaf are all much reduced so that several heads appear much branched and closely compacted, as shown at points indicated as 3 on PLATE 12. In some plants the ultimate branches are well developed and the clusters contain few heads involving only the last few ranks of ultimate branches. Such rather simple grouping is shown in PLATE 13, *A*, in the series of laterals, all from the same plant, which show a graded transition from a lateral with a terminal and three sessile laterals (1); to two laterals (3); to one lateral (4, 5, 6, and 7); the series illustrating successive stages of shortening of branches. *B* of the same plate has a somewhat more marked development of secondary laterals. In other cases there is little development of penultimate branches, so that clusters of numerous heads are frequent and the general branching is more sparse. The branches shown in the plate are near the apex of the main or large basal laterals; the larger main laterals near the base of a plant have larger laterals near their bases, which in turn duplicate the branching system of the more terminal parts of the main branches.

As all flower heads are in reality terminal for the particular branches, the distinction of terminal and lateral heads is purely a relative one. A terminal head blooms before a head that is immediately lateral to it. Thus in PLATE 13 the heads marked *a* in each case bloom before the one (*b*) lateral to it with branches *A*, 1–3; however, *a* blooms first, but the next to bloom is *b*, the terminal of the most basal cluster rather than *c*, which is immediately below the head *a*. The same general behavior holds for such cases of reduced branching as are shown in *C* and *D* of PLATE 13.

B. *Statistical studies regarding position.*

A complete study of the flower number per head according to position of terminals and laterals for all parts of the plant would involve a series of numbering from all apices to base in succession for all branches. For plants of the simplest branching even, this would be a very involved study. However, some clue to the relationship between position, time of blooming, and flower number can be gained by a comparison of terminals with heads that are immediately lateral to them. Such data may be obtained without discrimination between various branches, or they can be obtained separately for each of the main lateral branches.

Data from the intensive study last mentioned above have been obtained from five plants. The flowers of the heads were counted and the data recorded with respect to position on the various branches. All heads were counted with the exception of those that opened on Sundays or on days of heavy rainfall so that the data are nearly complete for all flower heads.

The behavior of one of these plants is recorded in TABLE 24. The data were collected in 1915 from an F_1 plant of wild white × Barbe de Capucin, {($A \times E_3$) *no.* 4}, which was then three years old. The data are given for the unbranched portion of the terminal axis and for the various successive lateral branches. The numbers in Roman are averages for terminal heads, either solitary or in a cluster, and the numbers in italics are for laterals, the averages being computed for each day. The daily averages for terminals and laterals are given for all branches. In quite the same manner the performance of another plant, an F_3 of the cross wild white-flowered × Barbe de Capucin {($A \times E_{22}$) –9–4–*no.* 14} in the first year of bloom is presented in TABLE 25.

We may first consider the comparison of relative numbers and values for terminals and laterals as such as to time of development. For the plant reported in TABLE 24, no laterals opened during the

TABLE 24

Seasonal distribution of flower number per head for third year of bloom of an F_1 generation plant ($A \times E_3$) *no. 4*, derived by crossing the wild plant (A) and a plant of Barbe de Capucin (E_3), daily averages arranged according to position of branch and of head on branch. Data for 1915. (Terminals, in ordinary type; laterals, in italics)

Branches starting at top	June		July																				August				
	29	30	1	2	3	6	7	8	9	10	12	13	14	15	16	17	20	22	26	27	29	31	5	6	7	10	16
Main	....	....	....	19.0	18.3	18.0	....	....	16.0	....	....	....	19.0	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	....	....	....	....	....	....	....	....	*18.0*	*19.0*	*19.5*	*17.0*	....	*19.0*	....	*18.5*	*19.0*	....	....	*17.5*	*18.0*	....	....	....	....	....	....
1	....	....	19.0	....	....	....	19.0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	*19.0*	....	....	....	....	....	....	*15.0*	....	....
2	....	....	19.0	....	....	20.0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	....	....	....	....	....	....	....	....	....	....	....	....	....	*19.0*	*19.0*	....	....	....	....	....	....	....	....	....	....	....	....
3	....	....	19.0	....	....	19.0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	*15.0*	....	....	....	....	....
4	....	20.0	....	....	....	19.0	....	....	....	....	....	18.0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	....	....	....	....	....	*18.0*	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
5	....	20.0	....	....	19.0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	....	....	....	....	....	....	....	....	....	....	*18.0*	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
6	19.0	....	....	....	19.0	....	....	....	20.0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	*15.0*	....	....	....	....	....	....	....	....	....
7	....	20.0	....	17.0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	....	....	....	....	....	....	....	....	*19.3*	....	*18.0*	....	....	....	....	....	....	*16.0*	....	....	*17.0*	....	....	....	....	....	....
8	....	....	19.0	20.0	....	....	19.5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	....	....	....	....	....	....	*19.0*	*16.0*	....	....	*19.0*	*19.0*	....	*19.0*	....	*18.0*	*18.0*	....	....	*18.0*	*18.0*	....	....	....	....	....	....
9	....	....	19.5	20.0	19.0	19.0	....	....	....	....	....	....	....	....	....	*19.0*	....	....	....	....	....	....	....	....	....	....	....
	....	....	....	....	....	....	....	*18.0*	*17.0*	....	....	....	*19.0*	....	....	....	....	....	....	....	....	....	....	....	....	....	....
10	....	....	....	20.7	19.0	19.0	18.0	18.5	....	....	....	19.0	19.0	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	....	....	....	....	....	....	....	....	....	....	*19.0*	....	....	*18.0*	....	*17.5*	....	....	....	*18.3*	....	....	....	....	....	....	....
11	....	....	....	19.0	20.0	20.0	18.8	19.0	17.5	....	....	....	....	....	....	*17.0*	....	....	....	....	....	....	....	....	....	....	....
	....	....	....	....	....	....	....	....	*19.0*	....	....	*15.5*	*18.0*	....	*18.0*	*18.0*	....	....	....	....	....	....	....	....	....	....	....
12	....	....	....	19.3	19.5	....	18.5	....	....	....	....	....	....	....	19.0	....	18.0	....	....	....	....	....	....	....	....	....	....
	....	....	....	....	....	....	....	....	....	....	....	*16.0*	....	....	*17.0*	*17.3*	....	....	*16.3*	*18.5*	*17.0*	....	....	....	....	....	....

TABLE 24—*Continued*

Branches starting at top	June		July																				August				
	29	30	1	2	3	6	7	8	9	10	12	13	14	15	16	17	20	22	26	27	29	31	5	6	7	10	16
	....	....	....	20.3	20.7	18.8	18.0	19.5	17.0	....	17.0	17.5	....	....	....	....	....	....	....	....	17.0	....	....	....	....	....	....
13	....	....	....	....	....	....	....	....	....	....	*16.0*	....	*17.0*	*19.0*	*18.5*	*17.0*	*16.0*	....	....	*18.0*	*16.5*	....	....	*19.0*	....	....	....
	....	....	....	20.0	....	19.5	....	17.7	17.0	17.0	17.7	17.3	16.0	17.0	....	*18.0*	....	....	....	....	....	....	....	....	....	....	....
14	....	....	....	....	....	....	....	....	*15.0*	....	*17.5*	*18.0*	....	*17.3*	*17.0*	*18.5*	....	....	*15.0*	*16.0*	*15.5*	....	....	*16.0*	....	....	....
	....	....	....	19.0	20.3	19.0	....	18.0	17.0	17.5	17.2	17.5	18.0	17.0	....	....	....	....	....	....	....	....	....	....	....	....	....
15	....	....	....	....	....	....	....	....	....	....	*19.0*	....	....	*18.5*	....	....	*18.8*	*17.7*	....	*16.0*	*16.3*	....	....	....	....	....	....
	....	....	....	19.5	19.5	18.2	18.7	18.2	18.3	17.7	17.5	17.0	17.0	....	....	....	....	....	....	....	....	....	....	....	....	....	....
16	....	....	....	....	....	....	....	....	....	....	....	....	....	*19.0*	....	....	....	....	....	*16.0*	*17.0*	....	....	....	....	....	....
	....	....	....	....	....	19.5	18.5	19.3	18.2	19.0	16.8	....	....	17.5	18.0	17.0	15.0	....	....	....	....	....	....	....	....	....	....
17	....	....	....	....	....	....	....	....	....	....	....	*17.0*	....	....	....	....	*16.0*	*16.0*	*16.0*	....	....	*16.0*	....	....	*19.0*	....	....
	....	....	....	....	....	19.5	....	....	18.4	18.6	17.4	16.8	20.0	15.6	17.0	17.3	....	17.0	....	....	18.0	....	....	....	....	....	....
18	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	*18.0*	*17.7*	*19.0*	....	....	....	....	....	*19.0*	*16.0*	....
	....	....	....	....	....	....	19.0	17.0	17.5	18.0	17.0	18.0	16.7	....	....	....	....	16.0	....	....	....	....	....	....	....	....	....
19	....	....	....	....	....	....	....	....	....	....	*16.0*	....	....	....	....	....	....	....	*15.5*	*16.7*	*18.0*	....	*16.7*	....	....	....	....
	....	....	....	....	....	19.0	....	....	18.0	17.7	17.3	17.7	16.6	16.8	16.6	16.2	16.5	16.2	14.0	....	....	....	....	....	....	....	....
20	....	....	....	....	....	....	....	....	....	....	....	....	....	*15.0*	*17.0*	*16.0*	*18.0*	*17.0*	*17.0*	....	*16.3*	*16.0*	....	....	....	....	*16.0*
	....	....	....	....	....	17.0	18.5	20.0	17.7	18.0	17.8	17.5	18.2	17.3	17.5	17.7	17.0	....	....	....	....	....	....	....	....	....	....
21	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	*18.0*	*17.5*	*17.7*	*17.0*	....	....	....	....	....	....	*16.0*	....
	....	....	....	....	....	20.0	18.5	18.0	15.0	16.0	16.8	17.3	16.8	16.6	16.2	17.5	16.0	....	....	....	....	....	....	....	....	....	....
22	....	....	....	....	....	....	....	....	....	....	....	....	*17.0*	....	....	*16.0*	*16.0*	*17.0*	*16.0*	....	*17.0*	*14.7*	....	....	....	*16.0*	....
	....	....	....	....	....	19.0	....	19.5	....	16.5	18.3	17.3	17.0	15.3	17.0	18.3	17.0	....	....	....	....	....	....	....	....	....	....
23	....	....	....	....	....	....	....	....	....	....	....	....	....	*15.0*	....	*17.3*	*16.5*	....	*16.0*	*16.3*	....	*17.5*	....	....	....	....	....
	....	....	....	....	....	19.0	19.0	18.0	....	17.7	17.3	16.7	17.6	17.4	....	....	....	....	....	....	....	....	....	....	....	....	....
24	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	*16.0*	*16.8*	....	*17.0*	*16.0*	....	....	....	....
	....	....	....	....	....	18.3	....	....	19.0	....	16.5	16.3	17.2	17.1	16.5	13.0	16.1	....	....	....	....	....	....	....	....	....	....
25	....	....	....	....	....	....	....	....	....	....	*16.0*	....	*16.5*	*15.5*	*16.3*	....	*17.0*	*16.3*	*16.5*	*17.3*	*17.0*	*16.0*	....	....	....	....	....
No. of heads with averages	1	3	6	22	22	47	28	36	41	42	57	48	40	44	29	22	18	8	2	....	3	....	....	....	....	....	....
	19.0	20.0	19.2	19.7	19.6	18.9	18.6	18.4	17.7	17.7	17.2	17.2	17.3	16.9	16.9	16.9	16.6	16.7	15.0	....	17.7	....	....	....	....	....	....
	....	....	....	....	....	*1*	*1*	*3*	*7*	*1*	*12*	*8*	*7*	*17*	*12*	*23*	*23*	*25*	*16*	*26*	*22*	*13*	*3*	*2*	*3*	*3*	*3*
	....	....	....	....	....	*18.0*	*19.0*	*17.3*	*18.1*	*19.0*	*18.2*	*16.7*	*17.3*	*17.3*	*17.2*	*17.3*	*17.5*	*17.5*	*16.4*	*17.2*	*16.7*	*16.0*	*16.7*	*17.5*	*17.7*	*16.0*	*16.0*

TABLE 25

SEASONAL DISTRIBUTION OF FLOWER NUMBER PER HEAD FOR FIRST YEAR OF BLOOM OF PLANT (*A*) AND A PLANT OF BARBE DE CAPUCIN (E_{22}), DAILY AVERAGES ARRANGED (Terminals, in ordinary type; laterals, in italics)

Branches starting at top	June												July		
	16	18	19	22	23	24	25	26	27	28	29	30	1	2	3
Main	17.0	17.0	17.5	....	....	....	....	....	....	....	....	....	....	....	....
	....	....	....	*16.5*	*17.0*	....	*16.0*	....	*16.0*	....	....	*15.0*	....	....	*16.0*
1	17.0	19.0	....	....	16.0	....	....	....	....	....	....	....	....	....	....
	....	....	....	....	....	....	....	....	*17.0*	....	....	....	....	....	....
2	16.0	17.5	....	....	....	....	19.0	....	....	....	....	....	....	....	....
	....	....	....	*16.0*	....	....	*17.0*	....	....	*18.0*	....	....	....	*17.0*	....
3	....	....	17.0	17.0	....	....	....	....	....	....	....	....	....	....	....
	....	....	....	....	*16.0*	*17.5*	....	*17.0*	....	....	*16.0*	*19.0*	*16.0*	....	....
4	....	....	....	....	17.0	19.0	16.0	....	....	....	15.0	....	....	....	....
	....	....	....	....	....	....	....	....	....	....	....	*17.0*	*16.8*	....	....
5	....	....	....	....	17.0	....	16.0	18.7	....	....	18.0	15.0	16.0	....	....
	....	....	....	....	....	....	....	....	....	*17.0*	....	....	*16.0*	....	....
6	....	....	....	....	17.0	....	....	19.0	20.0	17.0	....	16.0	....	....	....
	....	....	....	....	....	....	....	....	*17.5*	*17.0*	....	*16.5*	*16.5*	*15.5*	*16.5*
7	....	....	....	....	....	19.0	19.0	19.0	16.0	18.0	....	15.0	....	16.0	....
	....	....	....	....	....	....	....	....	*17.5*	....	*16.0*	*15.0*	....	*15.0*	*15.0*
8	....	....	....	....	....	....	....	17.0	16.5	....	15.0	17.0	....	16.0	....
	....	....	....	....	....	....	....	....	....	*16.0*	....	....	*16.3*	*15.7*	*15.5*
9	....	....	....	....	....	19.0	18.0	19.0	17.0	....	16.0	16.5	15.0	....	15.5
	....	....	....	....	....	....	....	....	....	*16.0*	....	*15.0*	....	*16.5*	*16.0*
10	....	....	....	....	....	....	....	19.0	18.0	16.5	....	16.0	16.5	16.0	....
	....	....	....	....	....	....	....	....	....	....	....	....	....	*15.0*	*16.7*
11	....	....	....	....	....	....	....	....	17.0	....	16.0	17.5	18.0	....	17.0
	....	....	....	....	....	....	....	....	....	....	....	*17.0*	*16.0*	....	*16.5*
12	....	....	....	....	....	....	....	....	....	16.0	....	....	....	16.7	16.0
	....	....	....	....	....	....	....	....	....	....	....	....	*16.0*	....	*15.5*
No. of heads with averages	4	6	3	1	6	3	5	10	7	7	6	11	5	7	6
	17.2	17.4	17.3	17.0	16.8	19.0	18.0	18.5	17.4	16.7	16.0	16.3	15.4	16.3	15.8
	....	....	....	*4*	*2*	*2*	*2*	*1*	*6*	*6*	*2*	*8*	*16*	*10*	*22*
	....	....	....	*16.5*	*16.5*	*17.5*	*16.5*	*17.0*	*16.7*	*16.8*	*16.0*	*16.4*	*15.3*	*15.8*	*15.9*

first five days of bloom; no data were obtained on the sixth and seventh days of bloom, but on each of the eighth and ninth days one head opened. From then on the number of such heads gradually but steadily increased and the number of terminal heads decreased. From July 29 to the end of blooming period (August 16) only lateral heads bloomed.

It is also plain that the average number of flowers per head for both terminals and laterals steadily decreases as the season of bloom advances, and that both the maximum and minimum numbers are lower for laterals. In respect to the total number of flower heads, only indirectly shown by averages in tables, there is

TABLE 25—*Continued*

AN F_3 GENERATION PLANT (*A* × E_{22})-*9-4- no. 14*, DERIVED FROM CROSSING THE WILD
ACCORDING TO POSITION OF BRANCH AND OF HEAD ON BRANCH. DATA FOR 1915.

July															August	
6	7	8	9	10	12	13	16	17	19	20	26	29	30	31	2	6
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	*14.0*	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	*16.0*	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	*17.0*	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	*15.5*	....	....	....	....	*16.0*	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
16.7	....	....	....	....	....	....	....	*17.0*	....	....	....	....	....	*17.0*	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	*15.5*	....	....	....	*12.0*	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
16.5	*15.0*	....	....	....	....	....	....	....	....	....	....	....	....	....	*12.0*	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	*16.0*	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
15.3	....	....	*15.0*	....	*15.0*	*16.0*	....	....	....	....	....	....	....	*15.5*	....	....
16.0	....	....	15.0	....	....	....	....	....	....	....	....	....	....	....	....	....
15.5	....	....	....	*15.0*	*16.0*	....	....	....	*14.0*	....	....	*15.0*	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	15.0	....
15.3	....	....	*19.0*	*15.0*	....	*15.0*	*17.0*	....	....	....	....	*15.5*	*14.5*	*14.3*	*14.7*	*15.0*
2	....	....	1	....	....	....	....	....	....	....	....	....	....	....	1	....
16.5	....	....	15.0	....	....	....	....	....	....	....	....	....	....	....	15.0	....
13	*6*	*4*	*3*	*2*	*3*	*3*	*1*	*1*	*1*	*3*	*3*	*3*	*2*	*7*	*5*	*1*
15.8	*14.8*	*15.8*	*16.3*	*15.0*	*15.0*	*15.8*	*17.0*	*17.0*	*14.0*	*15.7*	*16.0*	*15.7*	*14.5*	*14.7*	*14.0*	*15.0*

also quite similar performance in that the maximum number for both terminal and laterals is about midway in the period of their appearance; the maximum for laterals therefore is on a date slightly later than the maximum for terminals.

In comparing the terminals and laterals as summarized in respect to rate of decrease (*b*) and value of first day of bloom (*a*) some differences appear. The terminals bloomed for a period of 28 days and gave a value of 19.6 for *a* and for *b* of −0.138. The laterals bloomed 41 days and for these the value of *a* is 18.0 and for *b* is −0.045. The rate of decrease in number per head for the laterals is less than that of the terminals.

The other four plants, which were studied intensively, agreed with the behavior reported above for general performance of terminal and laterals. However, minor differences were present, so the performances of no two plants were identical in detail. This may be shown by data for one other plant as given in TABLE 25. Here the laterals came into bloom much sooner and a few terminals appeared very late in the season.

We may now consider the relative performance of different branches of a plant.

For the plant reported in TABLE 24, the first head to bloom was situated on the lateral branch that was sixth in rank from the top. On the following day a head opened on each of branches no. 4, 5, and 7; on the next day heads opened on 1, 2, 3, 8, and 9; on the following day heads bloomed on the main terminal branch and on 10–16. No data were collected on the 4th and 5th, but on the 6th, or eight days after first bloom, all the main and all the lateral branches of the plant had produced at least one flower head.

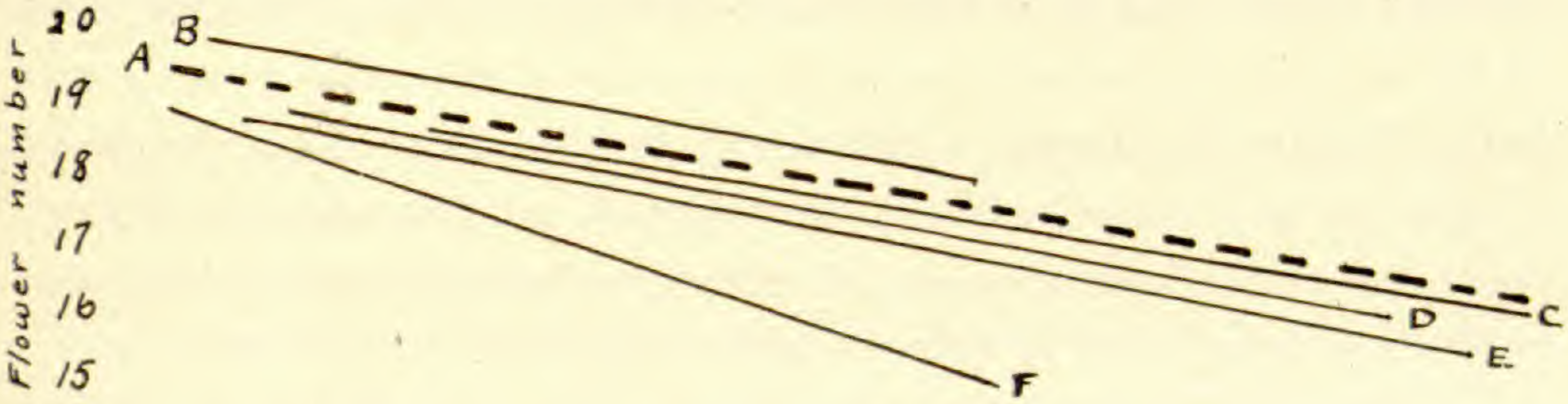
In general the performance of each branch is quite like that of the plant as a whole. Terminals come into bloom first, laterals continue to bloom later than terminals, the average flower number per head decreases as the season advances. A comparison of the performance of different branches, however, shows that the averages of the first flower heads on most branches are not decidedly different, which means that the rate of decrease in average number per head for a plant as a whole is usually less during the first part of the season while the different branches are coming into bloom than it is later when all branches have come into flower and most of the first terminals have bloomed.

Individual differences for the various branches in the relative time of blooming are in evidence and constitute a factor contributing to the rate of decrease as determined. For the plant reported in TABLE 25 eleven days elapsed before all the main branches were in bloom. Some irregularity was also seen in that the seventh and ninth branches started bloom with higher values per head (19) than were realized in the first heads to bloom on branches 1, 2, 4, 5, and 6. Such a performance influences the actual curve of average flower number and rate of change for the plant as a whole, giving for the first few days an actual increase in the average.

The relative average performance of each branch and the average performance of the plant as a whole are shown for each of the two plants discussed above in the diagrams of TABLES 26 and 27. To avoid the complication of many lines, branches that started to bloom on the same day were averaged as indicated.

TABLE 26

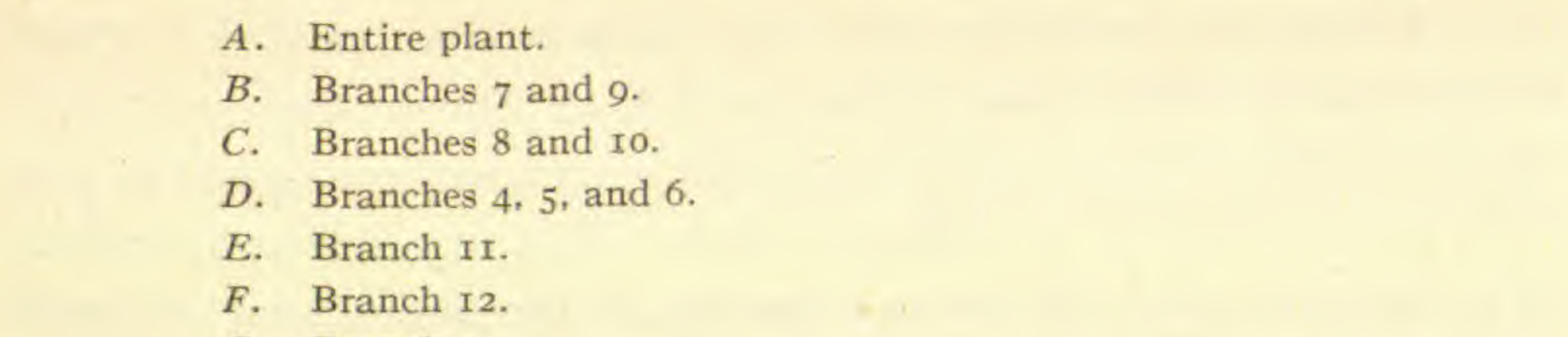
DIAGRAM SHOWING DECREASE IN FLOWER NUMBER PER HEAD FOR PLANT $(A \times E_3)$ *no. 4* AS A WHOLE AND FOR ITS DIFFERENT BRANCHES DURING A SINGLE SEASON OF BLOOM. DRAWN TO A SCALE WITH ORDINATES GIVING FLOWER NUMBER AND ABSCISSAS REPRESENTING PERIODS OF BLOOM



A. Entire plant.
B. Branches 4, 5, and 7.
C. Branches 17 to 25.
D. Unbranched portion of main axis and branches 10 to 16.
E. Branches 1, 2, 3, 8, and 9.
F. Branch 6.

TABLE 27

DIAGRAM SHOWING DECREASE IN FLOWER NUMBER PER HEAD FOR PLANT AS A WHOLE AND FOR DIFFERENT BRANCHES. FROM DATA OF PLANT $(A \times E_{22})$*–9–4–no. 14*. ORDINATES ARE FLOWER NUMBER PER HEAD; ABSCISSAS REPRESENT PERIODS OF BLOOM



A. Entire plant.
B. Branches 7 and 9.
C. Branches 8 and 10.
D. Branches 4, 5, and 6.
E. Branch 11.
F. Branch 12.
G. Branch 3.
H. Unbranched part of main axis and branches 1 and 2.

The performances of the different branches of the plant shown in TABLES 24 and 26 were more similar than those of the different branches of the plant reported in TABLES 25 and 27. The graphs in the latter case overlap and cross and the graph for the plant as a whole is less in agreement with that of a single branch.

From such studies of the individual behavior of the different branches we gain some clue to the immediate causes of the irregularities which appear in the data collected from day to day, and of the irregularities that appear in the rate of decrease in the number of flowers per head. Differences in the relative development of the various branches, and the number of branches produced, have a marked influence on the average flower number observed from day to day and in the corresponding rate of decrease.

It is apparent that the irregularities are due chiefly to variations in behavior of the different branches during the first twenty or twenty-five days of blooming and are chiefly due to the number of branches and to the rate with which these come into bloom. The averages for the whole plant may show no decrease, a very slight decrease, or even a slight increase (see TABLE 27) during the period of first blooming, due to the fact that day after day for a longer or shorter time new branches begin to bloom all with a high flower number per head. If, however, a considerable number of branches have been in bloom for some time and are showing a marked decrease in flower number per head when late branches come into bloom, the higher flower numbers of the latter will for a time retard the rate of decrease. The irregularities occur chiefly at the beginning and the end of the period of blooming. In all cases the rate of decrease is less until all branches are in bloom.

It would appear that the most typical development of a plant is such that the branches from the oldest to the youngest show characteristic differences in the number of flowers per head and in the rate of decrease, which may be somewhat analogous to the behavior of a plant at different ages. The uppermost branches in comparison with the lower branches of the same plant are, as a rule, smaller, have fewer heads, bloom for a shorter period, and show less decrease in flower number. While the variations in and among the various branches of different plants considered as wholes are so pronounced that a perfect or exact type of development of this sort is not realized, the strong tendency to such a type is more or less evident from the data which show that there is a decrease for branches according to the relative time of blooming, which merges into and contributes to the general decrease of the flower number for the plant as a whole.

The more absolute calculation of the decrease of average number per head, therefore, involves the factor of position of the various branches involving their age, length of life, and number. This decrease, due to position, may be considered as an unknown c and its value calculated in the same manner as that of b. If n be used to represent the number of the branch, we may introduce these two new factors into the equation which now becomes $o = a + bt + cn$. Three simultaneous equations can be developed by the same methods already used, giving

(1) $[o] = a + b\,[t] + c\,[n]$

(2) $[ot] = a\,[t] + b\,[t^2] + c\,[tn]$

(3) $[on] = a\,[n] + b\,[tn] + c\,[n^2]$

In order that the rate of decrease for each branch be given its full weight, uninfluenced by the high flower number of the branches that begin to bloom later, the data were so arranged that the same starting point was taken for all branches; that is, all the observations for first day of bloom, second day of bloom, etc. were grouped together, regardless of dates. From TABLE 28 the values of a, b, and c for the plant $(A \times E_3)$ *no.* 4 were calculated. In order to simplify the calculations the observations are put down as + and − deviations from 18.0.

Comparisons show that both series of calculated values correspond fairly well with the observed values. It does not, of course, appear from the data on this one plant that the values computed when both time and position are taken into account are in better agreement with the observed values than if time alone be considered. In order that the reader may judge of the amount of agreement, there is presented for comparison in TABLE 29 (1) the flower numbers actually observed on various dates after the first day of bloom without taking position into account, (2) the theoretical values for the same dates with regard to the factor of time, and (3) the values when both time and position are taken into account.

TABLE 28

TABLE FOR CALCULATION OF VALUE OF FIRST DAY OF BLOOM (*a*), WHERE POSITION OF HEAD UPON WHICH DATA OF SEASONAL DISTRIBU

Branches, starting from top	Days															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Main	1.0	0.2	.....	.....	0.0	.....	.....	− 1.0	1.0	.....	1.5	− 1.0	1.0	1.0	.....	0.5
1	1.0	.....	.....	.....	.....	.....	1.0	.....	.....	.....	.....	.....	.....	.....	.....	.....
2	1.0	.....	.....	.....	.....	2.0	.....	.....	.....	.....	.....	.....	.....	.....	1.0	1.0
3	1.0	.....	.....	1.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
4	2.0	.....	.....	.....	.....	.....	0.5	.....	.....	.....	.....	.....	0.0	.....	.....	.....
5	2.0	.....	.....	1.0	.....	.....	.....	.....	.....	.....	.....	.....	0.0	.....	.....	.....
6	1.0	.....	.....	.....	1.0	.....	.....	.....	.....	.....	.....	2.0	.....	.....	.....	.....
7	2.0	.....	−1.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.0	.....	.....	.....
8	1.0	1.0	2.0	.....	.....	.....	1.3	2.0	.....	.....	.....	1.0	1.0	.....	1.0	.....
9	1.5	2.0	1.0	.....	.....	1.0	.....	0.0	−1.0	.....	.....	.....	.....	1.0	.....	.....
10	2.7	1.0	.....	.....	1.0	0.0	0.5	.....	.....	.....	1.0	1.0	1.0	0.0	.....	−0.5
11	1.0	2.0	.....	.....	2.0	0.8	1.0	0.0	.....	.....	.....	− 2.5	.....	0.0	0.0	−0.5
12	1.3	1.5	.....	.....	.....	0.5	.....	.....	.....	.....	.....	− 2.0	.....	.....	0.0	−0.7
13	2.3	2.7	.....	.....	0.8	0.0	.....	− 1.0	.....	.....	−1.5	− 0.5	−1.0	1.0	0.5	−1.0
14	2.0	.....	.....	.....	1.5	.....	−0.3	− 1.0	.....	.....	−0.4	− 0.5	−2.0	−0.7	−1.0	0.3
15	1.0	2.3	.....	.....	1.0	.....	0.0	− 1.0	−0.5	.....	−0.4	− 0.5	0.0	0.0	.....	.....
16	1.5	1.5	.....	.....	0.2	0.7	0.2	0.3	−0.3	.....	−0.5	− 1.0	−1.0	1.0	.....	.....
17	1.5	0.5	1.3	0.2	1.0	.....	−1.2	− 1.0	−0.5	0.0	−1.0	− 2.7	.....	.....	−2.0	.....
18	1.5	.....	0.4	0.6	−0.1	.....	−0.6	− 1.2	2.0	−2.4	−1.0	− 0.7	.....	.....	0.0	.....
19	1.0	−1.0	−0.5	0.0	.....	−1.2	0.0	− 1.3	.....	.....	.....	.....	.....	.....	.....	.....
20	1.0	.....	.....	0.0	−0.3	.....	−0.7	− 0.3	−1.4	−1.5	−1.3	− 1.9	.....	.....	−1.0	.....
21	−1.0	0.5	2.0	−0.3	0.0	.....	−0.2	− 0.5	0.2	−0.7	−0.5	− 0.2	.....	.....	−0.7	.....
22	2.0	0.5	.....	0.0	−3.0	−2.0	−1.2	− 0.7	−1.2	−1.4	−1.8	− 1.0	.....	.....	.....	.....
23	1.0	.....	1.5	−1.5	.....	0.3	−0.7	− 1.0	.....	−2.8	−1.0	− 0.5	.....	.....	−1.2	.....
24	1.0	1.0	0.0	.....	−0.3	.....	−0.7	− 1.3	−0.4	−0.6	.....	.....	.....	.....	.....	.....
25	0.3	.....	.....	1.0	−0.8	.....	−1.6	− 1.7	−1.0	−1.5	−1.7	− 5.0	.....	.....	−1.5	.....
Totals...	33.6	15.7	6.7	2.0	4.0	2.1	−2.7	−11.7	−3.1	−9.6	−8.6	−16.0	−1.0	3.3	−4.9	−0.9

$[o] = -0.2$ $\qquad [t^2] = 187.79$

$[ot] = -8.3$ $\qquad [n] = 14.9$

$[on] = -7.1$ $\qquad [n^2] = 268.49$

$[t] = 10.8$ $\qquad [tn] = 160.37$

The collection of data and the calculations which take the rate of decrease of the various branches into account, while simple, are extremely laborious and consume much time. The collection of such extensive data for a very large number of plants is scarcely possible. Such data are desirable in the analysis of the sources of the variability and may indicate the proper methods of obtaining from a larger number of plants the data that will admit of more general analysis and comparison.

The question naturally arises whether in a plant with a long blooming-period such as chicory the random collection of data at intervals of every third day throughout the flowering period will

TABLE 28—*Continued*

PLANT IS TAKEN INTO CONSIDERATION. DATA FOR THE F_1 GENERATION PLANT ($A \times E_3$) *no. 4*, FOR
TION ARE PRESENTED IN TABLE 24

Days																Totals
16	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	
.....	1.0	.....	.....	.....	.....	.....	.....	− 0.5	.....	0.0	.....	.....	.....	.....	.....	3.7
.....	.....	.....	.....	1.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	−3.0	0.0
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	−3.0	.....	.....	2.0
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2.0
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2.5
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	3.0
.....	.....	.....	.....	.....	.....	.....	.....	− 3.0	.....	.....	.....	.....	.....	.....	.....	1.0
.....	.....	.....	.....	.....	−2.0	.....	.....	.....	.....	.....	.....	−1.0	.....	.....	.....	− 0.7
0.0	.....	0.0	.....	.....	.....	.....	.....	.....	0.0	.....	0.0	.....	.....	.....	.....	10.3
1.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.3	.....	.....	.....	.....	.....	6.8
.....	.....	.....	.....	.....	.....	.....	.....	0.3	.....	.....	.....	.....	.....	.....	.....	8.0
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	3.8
.....	0.0	.....	.....	.....	.....	.....	−1.7	0.5	.....	−1.0	.....	.....	.....	.....	.....	− 1.6
.....	−2.0	.....	−1.3	.....	.....	.....	.....	0.7	.....	.....	.....	.....	.....	.....	.....	− 0.3
.....	.....	.....	.....	.....	.....	.....	−3.0	− 2.0	.....	−2.5	.....	.....	.....	−2.0	.....	−11.6
.....	0.8	.....	−0.3	.....	.....	.....	.....	− 2.0	.....	−1.7	.....	.....	.....	.....	.....	− 1.3
.....	.....	.....	.....	.....	.....	.....	−2.0	.....	.....	−1.0	.....	.....	.....	.....	.....	− 0.4
−2.0	.....	.....	.....	.....	.....	0.0	.....	− 2.0	.....	.....	1.0	.....	.....	.....	.....	− 7.9
−1.7	.....	.....	1.0	.....	.....	.....	.....	.....	.....	.....	1.0	−2.0	.....	.....	.....	− 3.2
.....	.....	−2.3	−1.3	.....	.....	.....	0.0	− 1.3	.....	.....	.....	.....	.....	.....	.....	− 7.9
−1.3	.....	.....	−2.0	.....	.....	−1.7	.....	− 2.0	.....	.....	.....	.....	−2.0	.....	.....	−16.4
−0.3	.....	.....	−1.0	.....	.....	.....	.....	.....	.....	.....	.....	−2.0	.....	.....	.....	− 4.7
−1.0	.....	.....	−2.0	.....	.....	−1.0	.....	− 3.3	.....	.....	.....	.....	.....	.....	.....	−17.1
.....	.....	.....	−2.0	−1.7	.....	.....	.....	− 0.5	.....	.....	.....	.....	.....	.....	.....	− 9.1
.....	.....	.....	−2.0	−1.2	.....	.....	.....	− 2.0	.....	.....	.....	.....	.....	.....	.....	− 7.5
.....	.....	.....	−1.5	−0.7	.....	.....	.....	− 2.0	.....	.....	.....	.....	.....	.....	.....	−18.7
−5.3	−0.2	−2.3	−12.4	−2.6	−2.0	−4.7	−6.7	−19.1	0.0	−5.9	2.0	−5.0	−5.0	−2.0	−3.0	......

1 $-0.2 = a + 10.8b + 14.9c$

2 $-8.3 = 10.8a + 187.79b + 160.37c$

3 $-7.1 = 14.9a + 160.37b + 268.49c$

Solving, $b = -0.086$

$c = -0.095$

$a = +2.2\ (20.2)$

adequately represent the variations in flower number per head and give data for a rate of decrease for the plant as a whole which adequately considers the variation due to position. Some evidence on this point is to be had from the relative dates upon which branches with the same relative position come into bloom on dif-

TABLE 29

OBSERVED AND THEORETICAL VALUES OF FLOWER NUMBER PER HEAD FOR AN F_1 GENERATION PLANT ($A \times E_3$) *no. 4*, FROM DATA GIVEN IN TABLES 24 AND 28

Days of bloom	0	4	14	18	29
Observed values	19.0	19.6	17.8	17.2	16.8
Values computed for time ($a - 0.066t$)	18.9	18.6	18.0	17.7	17.0
Values computed for time and position ($a - 0.086t - 0.095n$)	19.0	18.4	17.5	17.6	16.2

ferent plants. Such data for the main and for the successive fifteen branches of seven plants are presented in TABLE 30. For each plant the date of first blooming of any branch is considered as zero and all later blooming calculated from this. Observations are not complete for all branches, as indicated by the dashes.

TABLE 30

RELATIVE DAY OF FIRST BLOOM FOR MAIN STEM AND 15 BRANCHES NUMBERED FROM TOP DOWN, FOR SEVEN PLANTS

Plants	1	2	3	4	5	6	7	Average
Branches, starting from above	Day of first bloom							
Main	0	1	—	4	0	6	5	2.7
1	0	—	0	3	0	3	11	2.8
2	0	1	—	3	0	2	6	2.0
3	1	1	2	5	2	2	5	2.6
4	1	1	2	1	5	1	5	2.3
5	1	0	2	1	5	1	4	2.0
6	1	0	—	0	5	0	4	1.7
7	—	2	—	1	6	1	3	2.6
8	1	4	4	3	8	1	2	3.3
9	1	4	4	3	6	6	1	3.7
10	1	5	4	4	8	6	0	4.0
11	3	4	2	4	9	8	0	4.3
12	3	5	—	4	10	10	0	5.3
13	3	5	4	4	—	—	3	3.8
14	3	5	4	4	—	—	5	4.2
15	3	—	4	4	—	—	8	4.8
None lower observed								

While the number of plants observed is not large, it is sufficient to show variations in the type of development and illustrates the fact that there is considerable variation in the position of the branch that first comes into bloom and likewise in the relative time in which branches similarly placed come into bloom. While it is generally one of the uppermost branches that blooms first, the general development of a plant with respect to size, number of branches, etc., may be such that, as seen in plant no. 7 of TABLE 30, the 10th, 11th and 12th branches from the top may bloom first. The largest variability for branches of any one position is eleven days, seen in the first from the top, and the least is two days, exhibited by branches 13 and 14.

In spite of these irregularities, it appears that for the average relative date of bloom for the different branches of individual plants there is little individual variability and that one may secure quite adequate data by making collections from the plant as a whole, especially when the data are well distributed over the season and form a rather large total.

C. *The phenomenon of intermittent annual growth.*

Opportunity for further study of the influence of position and time of development on the number of flowers per head was given by a very marked variation of vegetative habit, giving discontinuous development or two periods of growth in a single year.

TEXT-FIGURE 1. Two plants of the race (race 3) exhibiting intermittent growth. Photo taken late in autumn.

To left a plant with first growth cut away, leaving only second growth.

To right a plant showing both first and second growth. The first growth was about twice as tall as the second and when photographed was dead and dry while the second growth was green and flowering profusely.

As a rule the seasonal development of the various branches is so continuous and overlapping that there is a sequence of bloom and no interruption in the blooming of a plant as a whole. The last to develop of the main laterals are the most basal of the laterals and are from the uppermost of the rosette leaves.

TABLE 31

SEASONAL DISTRIBUTION OF FLOWER NUMBER PER HEAD FOR A ONE-YEAR-OLD PLANT OF AN PLANT (A) AND A PLANT OF BARBE DE CAPUCIN (E_{22}).

Number of flowers per head	August											September				
	2	5	8	10	12	15	17	21	24	26	29	1	5	7	11	13
	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....
13	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....
14	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	1	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....
15	....	....	....	....	*1*	....	*1*	*1*	....	....	....	*1*	....	....	*1*	....
	3	3	2	4	4	4	....	2	....	....	....	1	....	....	....	....
16	....	....	*2*	*1*	....	*2*	*6*	*1*	*3*	*3*	*5*	*1*	*2*	....	*1*	*2*
	....	4	2	3	4	2	....	....	1	....	....	....	....	....	....	....
17	....	....	*1*	*1*	*1*	*2*	*2*	*4*	*6*	*3*	*3*	*6*	*3*	*7*	*4*	....
	....	1	....	1	1	....	....	1	....	....	....	....	....	....	....	....
18	....	....	....	....	....	....	....	*1*	....	*3*	*1*	*1*	*3*	*3*	*1*	....
	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....
19	....	....	....	....	....	....	*1*	....	....	*1*	*1*	....	*1*	....	....	....
	17.6	17.2	16.6	16.6	16.7	16.3	....	16.7	17.0	....	....	16.0	....	....	....	....
Averages..	....	....	*16.3*	*16.5*	*16.0*	*16.5*	*16.4*	*16.7*	*16.7*	*17.2*	*16.8*	*16.8*	*17.3*	*17.3*	*16.7*	*16.0*

Old growth [o] = 16.7 a = 16.9
[ot] = + 2.79 b = + 0.009
[t] = 26 t = 54
[t^2] = 271.55

In one line of descent there was a marked deviation from this habit of seasonal growth which was very striking in that an entire series of sister plants in 1916 exhibited this deviation. After the branches that usually develop were through blooming, young and new branches appeared from the axils of many of the rosette leaves (which had died); these continued to grow, making a bushy compact second growth quite distinct from the earlier growth both as to time of development and to position on the plant. This habit of growth is shown in TEXT-FIGURE 1. To the right is a plant with the growth of both periods shown; the older dead branches of the first period extend above the newer growth. To the left the old growth has been cut away, leaving only the branches of the second period. Between the close of the blooming of the first growth and the beginning of bloom on the second growth there was usually an interval of several days.

Complete data collected for the flower heads of two periods of growth for a single plant $\{(A \times E_{22})-9-5-12-\textit{no. } 6\}$ are pre-

TABLE 31—*Continued*

F$_4$ GENERATION (*A* × *E*$_{22}$)-*9-5-12- no. 6*, DERIVED FROM A CROSS BETWEEN THE WILD DATA FOR 1916. Terminals, in ordinary type; laterals, in italics)

September				October								November					
16	19	22	25	5-7	9-10	10-13	14-16	17-20	21-23	24-26	27-30	31-2	4-6	8-9	11-14	16	
....	....	....	....	....	....	....	....	....	1	....	1	....	....	....	....	....	Death
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
....	....	....	....	2	....	3	2	1	5	2	4	4	1	....	....	....	
....	*1*	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
....	....	....	....	3	2	2	7	9	2	7	1	2	2	3	2	....	
....	*1*	....	....	....	....	....	....	....	*2*	....	....	*1*	*2*	....	....	*1*	
....	....	....	....	1	1	1	1	....	....	2	....	....	1	....	....	....	
1	*1*	....	....	....	....	....	....	....	....	....	....	....	*3*	*1*	....	....	
....	....	....	....	....	....	....	....	1	....	....	....	1	....	1	....	....	
6	....	*1*	*1*	....	....	....	....	....	....	....	....	....	....	....	....	....	
....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	
1	*1*	*1*	....	....	....	....	....	....	....	....	*1*	....	....	....	*1*	....	
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
....	*1*	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
....	....	....	....	14.8	15.3	14.8	14.9	16.1	14.1	15.0	14.0	14.7	15.0	15.6	15.0	....	
17.0	*16.4*	*17.5*	*17.0*	....	....	....	....	....	*15.0*	....	....	*16.0*	*15.6*	*16.0*	*17.0*	*15.0*	

New growth $[o] = 14.9$ $a = 15.1$
$[ot] = +1.64$ $b = +0.011$
$[t] = 19$ $t = 42$
$[t^2] = 142.83$

sented in TABLE 31. The growth of the first period ended bloom on the 25th of September. The data collected for this period showed that the averages from day to day throughout indicate an increase in flower number per head ($b = +0.009$).

The new growth began bloom on the 5th of October and had only partly completed bloom when it was killed by frost. The data for the new growth are necessarily incomplete and mostly from terminal heads. Data were collected from the new growth every day, but to avoid extending the tables the data are summarized for every consecutive three days of collection; the totals for each column are therefore larger than when a column gives only data obtained in a single day. What was collected showed that there was here also an increase of number per head ($b = +0.011$).

The performances of the two periods were similar in yielding a slight increase in number per head. The average number per head and the value for the first date of bloom for the two were much higher for the first period. The lower branches which formed

TABLE 32

SEASONAL DISTRIBUTION OF NUMBER OF FLOWERS PER HEAD FOR A ONE-YEAR-OLD PLANT OF AN PLANT (*A*) AND A PLANT OF BARBE DE CAPUCIN (E_{22}). DATA FOR

Number of flowers per head	July	August										September					
	31	3	7	9	12	15	18	21	24	26	30	1	6	8	11	13	16
11	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	*1*
12	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	*1*
13	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	....	....	....	....	....	....	....	....	....	....	....	....	....	*1*	....	*1*	*1*
14	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	....	....	....	....	....	....	....	....	....	....	*1*	....	....	*3*	*1*	....	*1*
15	1	....	....	1	1	....	....	....	....	....	....	....	....	....	....	....	....
	....	....	....	....	*1*	*1*	....	*2*	*1*	....	*1*	*1*	*2*	*1*	*3*	*3*	*4*
16	1	1	6	5	1	....	2	....	....	....	....	....	....	....	....	....	....
	....	....	....	....	*2*	*5*	*2*	....	*2*	*2*	*3*	*6*	*4*	*2*	*3*	*2*	*1*
17	....	3	2	....	1	....	....	....	....	....	....	....	....	....	....	....	....
	....	....	*1*	*2*	*3*	*3*	*3*	*7*	*4*	*5*	*2*	*3*	*3*	*2*	*2*	*3*	*1*
18	....	3	....	2	....	....	....	....	....	....	....	....	....	....	....	....	....
	....	....	....	....	*1*	....	*3*	*1*	*1*	*2*	*2*	....	....	*1*	*1*	*1*	....
19	....	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	....	....	....	....	....	....	....	....	*1*	....	....	....	....	....	....	....	....
20	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	....	....	....	....	....	....	....	....	*1*	....	....	....	....	....	....	....	....
Averages	15.5	17.9	16.0	16.4	16.0	....	16.0	....	....	....	....	....	....	....	....	....	....
	....	....	*17.0*	*17.0*	*16.6*	*16.2*	*17.2*	*16.7*	*17.2*	*17.0*	*16.3*	*16.2*	*16.1*	*15.4*	*15.9*	*15.9*	*14.3*

Old growth $[o] = 16.1$ $a = 17.0$
$[ot] = -7.90$ $b = -0.032$
$[t] = 29$ $t = 57$
$[t^2] = 246.40$

the growth of the second period started in with lower average numbers per head.

Most plants of this race exhibited a minus value for rate of change (an actual decrease): the typical performance being as shown in TABLE 32. For this plant the growths of the two periods both show a rate of decrease. The values of *a* and [*o*] for the new growth are decidedly lower than those of the old growth.

4. INDIVIDUAL VARIATIONS FROM THE USUAL PERFORMANCES AS TO SEASONAL DECREASE

Marked deviations from the usual behavior of seasonal decrease have been found. Data for two such cases have already been given in TABLES 3 and 4.

TABLE 32—*Continued*

F_4 GENERATION $(A \times E_{22})$-*9-5-12- no. 31*, DERIVED FROM A CROSS BETWEEN THE WILD 1916. (Terminals, in ordinary type; laterals, in italics)

September				October									November				
19	22	25	27	5–7	9–11	13–14	16–17	18–20	21–23	24–26	27–28	30–1	2–4	6–8	9–11	14	
....	....	....	....	....	....	....	....	....	....	2	....	....	....	....	....	....	Death
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
....	....	....	....	....	....	....	1	....	....	2	....	....	1	2	....	....	
....	....	....	....	....	*1*	....	....	....	....	....	....	....	....	*1*	....	....	
....	....	....	....	2	4	3	3	....	2	4	2	2	1	1	4	1	
1	*1*	....	....	....	*1*	....	....	....	....	*1*	....	*3*	*1*	*1*	....	....	
....	....	....	....	8	7	4	9	3	4	7	5	2	3	6	6	2	
4	*3*	*1*	....	....	*1*	....	....	....	*1*	....	*1*	*8*	*2*	....	*1*	*1*	
....	....	....	....	2	1	3	3	4	3	8	4	7	2	6	4	....	
5	*5*	*5*	....	....	....	....	....	*3*	*1*	*1*	....	*1*	*1*	*2*	....	....	
....	....	....	....	2	....	1	1	1	1	1	....	2	1	1	1	....	
....	*1*	....	*1*	....	....	....	....	*1*	*1*	....	....	....	....	....	....	....	
....	....	....	....	....	....	....	....	1	....	....	1	....	....	....	....	....	
....	....	*1*	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
....	....	....	....	15.3	14.7	15.2	15.0	16.0	15.3	14.8	15.4	15.7	15.2	15.2	15.1	14.7	
14.4	*14.6*	*15.2*	*16.0*	....	*14.0*	....	....	*16.3*	*16.0*	*15.0*	*15.0*	*14.8*	*15.0*	*14.7*	*15.0*	*15.0*	

New growth $[o]$ = 14.9 a = 15.2
$[ot]$ = − 0.34 b = − 0.003
$[t]$ = 19 t = 40
$[t^2]$ = 123.00

These two plants were grown from seed in the summer of 1915; both were about 3 1/2 feet tall, rather sparsely branched, but with numerous flower heads, which were typically terminal and lateral. These plants were quite identical to all appearances in respect to habit of growth with numerous plants which gave a marked decrease in flower number as discussed above. Although data were not taken for terminal and lateral heads separately, it is evident that there were only slight differences between such heads. Time of blooming and position, it seems, were here not factors giving partial variability. The performance of such plants is indicated by the low values of *b*. If all plants exhibited such behavior, it would not be necessary to consider the seasonal performance in determining the values which were to be used for the comparison of the different individuals.

In the course of the studies a few plants were found which in the performance for a season exhibited an actual increase of average flower number per head. This is quite the reverse of the usual performance. Data for one of the most marked cases of such increase are given in the following table (TABLE 33). This plant was one of the F_4 generation grown in 1916 and the data as collected distinguished between terminals and laterals for the different clusters. The average or mean number for all flower heads is 17 and the value for the first date of bloom (*a*) is 16.4. Neither of these is an especially low value. It should be noted that this plant was one of a series of sister plants which were quite uniformly sparsely branched and had few solitary terminal heads: the heads were in clusters, quite as shown in *C* and *D* of PLATE 13. Such clusters evidently represent a shortened and compacted system involving terminals of different relative ranks with their respective laterals. The group is so compact that only the first head to bloom can be definitely regarded as terminal. If the group had not been compacted (but expanded as in *A* and *B* of PLATE 13), many of these heads would have been terminal for their respective clusters. The prevailing high numbers in the so-called lateral heads of these groups as seen in TABLE 33 may indicate that in these compacted groups of heads the laterals of lower ranks are crowded out and fail to develop as they may when the branching is more profuse. However, it must be recognized that many plants with the grouped-head habit, quite identical with the one under consideration, showed the seasonal decrease most characteristic of the species.

5. VARIATION IN PARTIAL VARIABILITY WITH THE AGE OF A PLANT

The data collected from plants in successive years of growth may now be presented with respect to the very important question of variation in seasonal performance of a plant from year to year. In the case of all perennials and especially of herbaceous perennials this point needs careful analysis before adequate comparisons between individuals can be made. All of the plants studied, with the exception of the variety red-leaved Treviso, grew as perennials, and although plants of each series winter-killed, the roots and basal portions of such plants were apparently fully alive at the end

TABLE 33

SEASONAL DISTRIBUTION OF FLOWER NUMBER PER HEAD FOR A ONE-YEAR-OLD PLANT OF AN F_4 GENERATION $(A \times E_{22})$-*9-5-12-no. 16*, DERIVED FROM A CROSS BETWEEN THE WILD PLANT (A) AND A PLANT OF BARBE DE CAPUCIN (E_{22}). DATA FOR 1916. (Terminals, in ordinary type; laterals, in italics)

Number of flowers per head	July	August										September									October				Total
	31	3	7	9	12	15	18	21	24	26	29	1	5	7	11	13	16	19	22	25	2	4	10	16	
14	....	....	....	....	....	....	....	....	....	....	....	....	....	*2*	....	....	....	....	....	....	....	....	....	....	*2*
	....	....	1	2	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4
15	....	....	....	....	....	....	....	*1*	....	*2*	....	*1*	....	*2*	*1*	....	....	....	*1*	....	....	....	....	....	*8*
	1	....	6	3	3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	13
16	....	.	...	*1*	....	*3*	*3*	*4*	*3*	*3*	*4*	*3*	*2*	*2*	*1*	....	*4*	*1*	*2*	....	....	*1*	....	....	*37*
	1	4	3	1	2	1	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	13
17	....	....	....	*2*	*3*	*2*	*5*	*1*	*2*	*2*	*4*	*5*	*7*	*2*	*6*	*1*	*5*	....	*3*	....	....	....	*1*	*1*	*52*
	1	2	....	1	1	1	....	....	....	....	....	....	....	....	....	....	..	....	....	....	....	....	....	....	6
18	....	....	....	....	....	*2*	*1*	*3*	*4*	*2*	*2*	*1*	*1*	*2*	*2*	*1*	....	*1*	*3*	*1*	....	....	*1*	....	*27*
	....	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4
19	....	....	....	....	*1*	....	....	*1*	....	....	....	....	....	....	....	....	*1*	*1*	*1*	....	*1*	*2*	....	....	*8*
Averages	17.0	18.0	16.2	16.1	16.7	17.5	15.0	....	17.0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	40
	....	....	....	*16.7*	*17.5*	*16.8*	*16.8*	*16.9*	*17.1*	*16.3*	*16.8*	*16.6*	*16.9*	*16.0*	*16.9*	*17.5*	*16.8*	*17.7*	*17.1*	*18.0*	*19.0*	*18.0*	*17.5*	*17.0*	*134*

$[o] = 17.0$ $a = 16.4$

$[ot] = +9.94$ $b = +0.018$

$[t] = 33$ $t = 77$

$]t^2] = 435.79$

of the previous season of growth. The plants of the red-leaved Treviso variety died at the end of the first season of bloom.

A perennial plant of chicory grown from seed exhibits considerable interannual variation in habit of growth, especially in the first and second years of growth and bloom. In the first year of bloom a single main erect stalk usually develops from the rosette; in the second year, usually, several main stalks are produced directly from the extreme basal and lower parts of the crown, or even from clusters of roots that may or may not have become separated by the death of the basal portions of the stem of the previous year. In a few years the cluster of roots is more or less increased in size and number and the group of main branches is correspondingly increased and more or less crowded together. The degree of such development varies considerably. The wild white-flowered plant *A* showed rather feeble increase or spread of this sort; the wild white-flowered plant *C* was somewhat more vigorous in its vegetative development; and plants of the Barbe de Capucin (*E* series) were most vigorous in this respect, so that from E_3 and E_{22} in the third year of growth a large number (15 or 20) of stems arose from the roots, and as some of these developed from small detached roots they were weak and late in developing. The crowding of such a number of stems also caused the poor development of many of them. For the perennial plants upon which data were collected, it has been the policy to allow no more than three or four main branches to develop. These were selected from the first shoots and were as nearly uniform in development as possible; all other weaker or later branches from the root cluster were cut away.

It has already been reported that in the second year of growth from seed, plants are taller and more branched and have a much longer flowering period with the production of many more flowers. These differences in general habit of growth are represented by such differences in data as appear between TABLES 8 and 9 for example. These differences raise the question whether such values as those calculated for the first day of bloom (*a*) and for the rate of decrease (*b*) are consistent for a plant in the successive years of its growth from seed.

Some judgment of this question may be gained by the correlation of data for those plants from which data were collected in different years. The following tables (34, 35, and 36) present such data, in values of *a*, which are grouped solely according to the age of the plants.

TABLE 34

Correlation between flower number for first day of bloom (*a*) of one-year-old and that of two-year-old plants

		Flower number of 2-year-old-plants									
		16	17	18	19	20	21	22	23	24	Averages
Flower number of 1-year-old plants	16			1	1						18.5
	17		1	7	3	3					18.6
	18			3	3	6					19.3
	19					4	2	1			20.6
	20			1	1	2	1				19.6
	21				1	1		1			20.3
	22										—
	23									1	24.0
	24										—

$r = +0.68$

TABLE 35

Correlation between flower number for first day of bloom (*a*) of three-year-old plants and that of one-year-old plants

		Flower number of 3-year-old plants							
		16	17	18	19	20	21	22	Averages
Flower number of 1-year-old plants	16	1		1					17.0
	17			1	5				18.8
	18				4		2		19.7
	19				2	6			19.8
	20					1	1		20.5
	21					1		1	21.0
	22								—

$r = +0.68$

TABLE 36

Correlation between flower number for first day of bloom of two-year-old and that of three-year-old plants

		Flower number of 3-year-old plants					
		18	19	20	21	22	Averages
Flower number of 2-year-old plants	18	2					18.0
	19	1	2	6	2	1	19.0
	20		10	2	3		19.5
	21		3	9	3	1	20.1
	22		1	2	1	1	20.4

$r = +0.60$

TABLE 34 presents the correlation of data for first and second year of blooming for 44 plants; the coefficient of correlation is +0.68. TABLE 35, involving 26 plants in the first and third years of growth, shows a coefficient of correlation of +0.68. The values of a from 50 two- and three-year-old plants show a coefficient of correlation of +0.60 (TABLE 36).

The values for the coefficient of correlation are remarkably uniform, which may be considered as more significant than the particular value. The correlation is also high, which, with the distribution in the tables, indicates very clearly that plants which exhibit a high value for a one year will also give high values in the following years. The value for a is strongly individual and tends to remain quite constant from year to year in spite of such differences as exist in the growth of plants in successive years. At least such is the case when the data used in the calculations are collected as described from plants grown as the chicory plants have been.

It should be pointed out that the plants utilized in this computation belong to a small number of lines of descent and that they are for the most part F_1, F_2, and F_3 progeny of crosses involving the wild white-flowered plants (A and C), and those of the cultivated variety (E_3 and E_{22}). The parents were widely different in general habit and the F_1 and F_2 generations likewise exhibited wide variations in such characteristics as height, vigor, general habit of branching, and period of blooming. The population as grouped in TABLES 34–36 is composed of five lines of descent. If these lines of descent showed great differences in flower number, the correlation from year to year would appear greater than it really is. From TABLE 37, however, it is evident that for plants of the same age the distribution of flower number in the different lines is essentially the same. In this table the frequencies of occurrence of flower number are recorded for each line separately. The interval used in grouping the flower number is 0.3; that is, the group 16.0–.2 includes 16.0, 16.1, and 16.2.

TABLE 37 shows data for different lines of plants in the first, second, and third years of growth. It will be seen that all the lines overlap. The series $(E_3 \times A)-4-$, an F_2 generation, is the only one that shows in the first and second year one plant with a very high value for *a*. The other plants of this series, however, show a range of variability similar to that of the other series. In the third year one plant of the series ($E_3 \times C$) had a very low number of flowers per head, but the rest of the series agrees with the general distribution of the other series.

TABLE 37

DISTRIBUTION OF FLOWER NUMBER PER HEAD (a) FOR ONE-YEAR, TWO-YEAR, AND THREE-YEAR-OLD PLANTS OF DIFFERENT LINES

Flower number	One year old											Two years old											Three years old							
	$A\times C$	$A\times E_3$	$E_3\times A$	$(E_3\times A)_{-4}$	$A\times E_{22}$	$(A\times E_{22})_{-4}$	$E_{22}\times A$	$(E_{22}\times A)_{-10}$	$C\times E_3$	$E_3\times C$	$C\times E_{22}$	$A\times C$	$A\times E_3$	$E_3\times A$	$(E_3\times A)_{-4}$	$A\times E_{22}$	$(A\times E_{22})_{-4}$	$E_{22}\times A$	$(E_{22}\times A)_{-10}$	$C\times E_3$	$E_3\times C$	$C\times E_{22}$	$A\times C$	$A\times E_3$	$E_3\times A$	$A\times E_{22}$	$E_{22}\times A$	$C\times E_3$	$E_3\times C$	$C\times E_{22}$
16.0–.2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
.3–.5	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
.6–.8	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..
.9–.1	..	..	..	..	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
17.2–.4	..	..	1	..	1	..	..	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
.5–.7	..	..	..	..	..	..	..	3	..	1	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
.8–.0	2	..	..	..	..	..	1	2	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..
18.1–.3	..	1	1	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	2	..	..	..	1	..	..	..	..	..	..	..
.4–.6	1	..	1	3	..	..	1	..	..	1	..	..	1	..	..	..	..	..	3	..	..	..	..	1	..	..	1	..	..	..
.7–.9	..	1	1	..	..	..	..	..	1	..	..	1	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
19.0–.2	..	..	1	..	..	..	..	..	..	..	1	..	1	..	..	..	..	..	1	..	..	..	..	..	1	2	..	1	..	..
.3–.5	..	..	1	..	1	..	..	..	..	1	..	..	..	..	1	..	..	..	..	1	1	..	1	3	3	1	2	1	2	..
.6–.8	..	..	..	1	..	..	..	..	1	..	..	1	1	1	..	..	1	3	..	..	..	..	..	..	1	..	..	1	1	..
.9–.1	..	..	..	..	1	..	1	..	..	..	1	..	..	..	1	1	2	..	..	..	1	..	1	1	3	2	..	..	1	..
20.2–.4	..	..	..	..	..	1	..	..	..	..	..	2	..	2	1	1	..	..	..	..	..	..	..	..	..	..	..	1	..	..
.5–.7	..	..	..	1	..	..	..	..	..	..	1	..	1	2	..	2	..	1	..	1	2	..	..	..	1	..	..	1	1	..
.8–.0	..	..	..	1	..	2	1	..	..	..	..	..	..	1	..	..	..	..	..	3	2	..	..	..	..	2	..	1	..	3
21.1–.3	..	..	..	..	..	..	..	..	..	..	..	1	..	..	1	1	..	..	..	1	..	1	2	..	..	..	..	..	..	1
.4–.6	..	..	..	..	1	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	3	..	..	..	..	1	1	..	..
.7–.9	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	2	..	..	..	1	..	1	..	..	..	..	..	..	..	1
22.0–.2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	1	1	..	..
.3–.5	..	..	..	..	..	..	..	..	..	..	..	..	1	1	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..
.6–.8	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..
.9–.1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
23.2–.4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
.5–.7	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
.8–.0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
24.1–.3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

It is quite evident then from this table that the differences in the distribution of flower number between the different series are not great enough to influence the coefficient of correlation for plants of different ages.

The plants *A* and *C* were at least in the third year of growth in 1913 when they were first used for data here reported. The general habit of growth of each was quite uniform in 1913, 1914, and 1915. The parents E_3 and E_{22} were in their second year of growth in 1913. During the winter of 1914–1915, the plant E_{22} was destroyed by pine mice. In the early spring of 1915 the roots of each plant (A, C, and E_3) were divided in two and grown as two plants, from which data were taken separately. The data for these various plants and for the hybrid generations are tabulated in TABLES 38 and 39.

It is clear from these comparisons that there is a rather close agreement in the behavior of a plant in successive years with respect to the production of flower number as determined by the calculated values for a. The nature of the development of a plant and the many factors contributing to fluctuations in development and production of flower number are such that exact agreement is not to be expected. The variations in the value of a for any one plant from year to year follow a rather uniform course. The value is, as a rule, lower for the first year of bloom than for the second and there is a further slight increase in the third year. The behavior of a plant is more uniform in the second and third years of growth. The data for plants A, C, E_3, and E_{22} indicate that such is also the case in later years.

TABLE 38

FLOWER NUMBER PER HEAD (a) IN THREE SUCCESSIVE YEARS OF PLANTS THREE OR MORE YEARS OLD. DATA FOR 1913, 1914, AND 1915

Plant	Value of a		
	1913	1914	1915
A	19.2	19.2	18.6 19.3
B	19.3	18.0	18.5 17.6
C	21.5	21.8	23.0 21.8
E_3	20.6	20.8	20.8 20.6
E_{22}	23.0	23.6	dead

TABLE 39 gives the values of a for plants of different ages, for the entire F$_1$ and F$_2$ population and for the various lines of descent. For the F$_1$ plants, as a group, the average the first year is 18.8; for the second year is 20.6 and for the third is 21.0; the average

TABLE 39

FLOWER NUMBER PER HEAD (*a*) FOR ONE-YEAR, TWO-YEAR, AND THREE-YEAR-OLD PLANTS

Plants	One year old		Two years old		Three years old		Increase in *a* from 1 year to 2 years	Increase in *a* from 2 years to 3 years
	Average *a*	Number of cases	Average *a*	Number of cases	Average *a*	Number of cases		
F_1's	18.8	36	20.6	55	21.0	105	+ 0.8	+ 0.4
$(A \times E_{22})$	19.1	9	20.7	10	20.9	35	+ 1.6	+ 0.2
$(E_{22} \times A)$	19.7	5	20.4	6	20.0	11	+ 0.7	− 0.4
$(E_3 \times A)$	18.6	6	21.1	8	19.8	12	+ 0.5	− 0.3
$(A \times E_3)$	18.4	3	20.3	6	19.1	9	+ 1.9	− 0.8
$(C \times E_{22})$	20.1	4	21.5	5	21.4	16	+ 1.4	− 0.1
$(E_3 \times C)$	18.4	4	20.4	6	19.4	7	+ 2.0	− 1.0
$(C \times E_3)$	19.3	2	21.0	8	20.5	8	+ 1.7	− 0.5
$(A \times C)$	18.1	3	19.8	6	20.0	7	+ 1.7	+ 0.2
F_2's	18.5	63	19.4	23	—	—	+ 0.9	—
$(A \times E_{22})$-*4-*	20.5	10	20.0	3	—	—	− 0.5	—
$(E_{22} \times A)$-*10-Ser. I*	17.6	11	18.2	10	—	—	+ 0.6	—
$(E_{22} \times A)$-*10-Ser. II*	17.1	15	—	—	—	—	—	—
$(E_3 \times A)$-*4-Ser. I*	19.7	10	19.5	10	—	—	− 0.2	—
$(E_3 \times A)$-*4-Ser. II*	19.2	17	—	—	—	—	—	—

increase of the second year over that of the first is just twice that of the third year over the second year. The F_2 generation has been studied only for the first and second year of growth, but has shown practically the same increase as did the F_1.

In regard to the behavior of the rate of decrease in successive years, it has been pointed out earlier in the paper that the rate of decrease becomes less as the blooming season becomes longer. Older plants are more vigorous than one-year-old plants and bloom longer. Because of this fact the rate of decrease becomes less as the plant grows older. The question whether various lines of descent are exhibiting diverse types of behavior, which are, however, characteristic of particular lines, will be more fully considered later.

6. VARIATION IN RANGE AND DISTRIBUTION OF MODAL NUMBERS

A survey of the facts regarding the maxima or modal numbers in chicory are of interest in relation to the question of specificity of flower number.

From data taken on an average of every third day throughout the period of bloom, it often appears, as may be illustrated in TABLE 10, that a well-pronounced maximum or mode is in evidence. In this particular instance there are 86 heads with 19 flowers per head, and about this mode there is quite a regular chance distribution. In other cases, the distribution is less regular and a mode is less pronounced. In no case, however, has there appeared evidence of a strongly bimodal distribution. Of course, data on all heads blooming on a plant would perhaps bring out the modal number more prominently. The collection of data during only a part of the blooming period would, of course, give quite different modes for any plant which exhibits a rate of change.

The range and distribution of the modal values for various groups of plants are given in TABLE 40. Several points are clearly indicated. The range of individual variability of modal numbers is rather wide and extends from 14 to 22. Interannual partial variability exists, as shown in the first section of the table, which presents data of a single generation in the first, second, and third years of growth. The distribution is somewhat irregular and the number of plants observed is not as large as one might wish, but the evidence is quite clear that the mode for a plant actually shifts to higher values at least during the first three years of growth.

TABLE 40

DISTRIBUTION OF MODES FOR FLOWER NUMBER PER HEAD FOR INDIVIDUALS OF VARIOUS GENERATIONS AND LINES OF DESCENT

Plants	Distribution of modes									Number of plants	Average mode
	14	15	16	17	18	19	20	21	22		
F_1 First year	....	3	9	7	13	2	3	1	....	38	18.4
Second year	....	....	2	4	2	26	11	7	....	52	19.1
Third year	....	....	1	4	1	30	11	15	1	63	19.5
F_3 and F_4											
$(A \times E_{22})$–*4*–	....	....	....	5	10	12	7	3	....	37	18.8
$(A \times E_{22})$–*9*–	2	41	31	41	3	....	....	....	....	118	16.0
$(E_{22} \times A)$–*10*–	....	10	31	84	7	11	....	....	....	143	16.8
Summary	2	51	62	130	20	23	7	3	....	298	16.8
R's 1916	1	13	12	17	14	10	9	3	....	79	17.4

The second section of the table presents data for the F_3 and F_4 generations of three main lines of descent in the first year of bloom. Here family differences are to be noted: highest values are seen in family $(A \times E_{22})-4-$ and lowest values are seen in family $(A \times E_{22})-9-$. It will be seen by comparison with TABLE 48 that these modes are high or low quite in agreement with values of *a*.

The modes for the 1916 crop of the variety red-leaved Treviso exhibit a rather wide range of variability, and the most frequent class is not strongly indicated but appears to be at 17. It will be shown later that the values of *a* for these plants (TABLE 42) are relatively high, although the range of variability of flower number is wide. The distribution for the whole season is somewhat skew and the low modal values are not an indication of the seasonal performance.

No attempt has been made to mass indiscriminately the total counts made into a general table. It is obvious that such a treatment would cover up individual and line differences, and the final value thus obtained would be modified by the proportionate number of individuals in the different races represented.

IV. CHARACTERISTICS OF FLOWER NUMBER IN THE VARIETY RED-LEAVED TREVISO

This variety is one of remarkable vigor of growth. Grown from seed sown in pans in a greenhouse during January there is vigorous and rapid growth, giving large rosette leaves of extremely robust habit and a large much-branched stem. The mature plants have been from 4 1/2 to 6 1/2 feet tall (see Fig. 1, Stout '17). When thus grown from seed the plants are annuals. The exceedingly vigorous growth usually reaches full maturity in late summer and early autumn and the plants are usually through blooming before the first late-autumn freeze.

The race grown has exhibited a type of teratological development which consists in the production of two stems sometimes completely separated above the crown, but usually united and somewhat twisted for a distance, above which the two merge into a single apparently normal stem. The fasciation usually does not extend to the flower branches and does not directly affect the individual flower heads. The extent of fasciation, the leaf shape, and the degree of pigmentation in this strain all show considerable variation, but the plants grown in all three years were quite similar in general vigor and habit of growth, although there was more or less variation in the number of branches and the length of the flowering period.

Data on flower number in this variety have been obtained from two parent plants of 1913, and from three generations (1914, 1915, and 1916 crops) derived by further intravarietal breeding. Until the summer of 1915 all plants (with the exception of one feebly self-fertile plant in 1915) were found to be self-sterile. The variety was kept in culture by crossing plants (usually immediate sister plants) that were cross-compatible.

As a result of the vigorous and robust growth in the lines grown of this variety as many as 2,000 to 3,500 flower heads per plant were produced. At the climax of development 100 or even 150 heads opened on a single plant in a single day. The period of bloom was also somewhat extended, but data were not used unless a plant completed its bloom before the first autumn freeze.

TABLE 41 presents data for one of these plants. For this plant the period of bloom extended from July 14 to October 21. There is a decided decrease in both daily range and average. The partial variability seen in the entire range from 31 to 7 was the greatest in both directions seen in any plant of this variety.

Of the crop of 1913, grown from commercial seed, there are data for the two plants which were crossed in obtaining seed from which all cultures were derived. For one of these the values obtained were $a = 19.5$, $b = -0.084$, and the range was 23–12; for the other plant $a = 17.4$, $b = -0.081$, and the range was 19–13. With respect to values of a, these two parent plants were somewhat diverse.

For the 1914 crop, data were obtained from nine plants: these gave values of a ranging from 18.6 to 20.8, with average of 19.8 ± 0.67. As shown in TABLE 42, the values of these plants are quite well distributed about the value of the parent having highest value of a.

In 1915, offspring were grown from crosses involving four sister plants (of the 1914 crop) for which the values of a were almost identical and were quite of the average. The average values for each line of descent according to immediate parentage

TABLE 41

SEASONAL DISTRIBUTION OF NUMBER OF FLOWERS PER HEAD FOR A PLANT OF RED-LEAVED TREVISO. DATA FOR 1916

Number of flowers per head	July						August											September										October						
	14	17	20	24	26	29	1	4	7	9	12	15	18	21	23	26	30	5	7	9	13	15	18	20	23	26	28	2	4	7	10	13	16	21
7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
9	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	1	...	...	...	...	1	...	...	...	...	...	...	...	...
10	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	2	...	1	...	...	1	...	...	...	...	...	...	...
11	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	...	2	...	...	...	1	...	...	1	...	2	1
12	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	1	4	2	1	1	...	2	2	...	...	1	...	...	...
13	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	2	1	2	1	1	1	1	2	2	...	...	1	...	...	...	...	1
14	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	1	1	...	2	1	...	...	2	1	1	...	1	1	1	...	2	1	...	1
15	...	...	...	...	...	...	...	...	...	2	1	1	2	1	1	1	3	4	3	...	2	...	3	1	4	1	1	2	1	1	2	...	1	...
16	...	...	...	...	...	...	...	...	...	...	...	3	2	1	1	1	4	2	...	2	1	1	1	2	2	2	2	1	1	1	...	4	...	...
17	...	...	...	...	...	...	...	1	1	1	3	3	1	3	3	...	...	...	4	2	1	...	1	1	...	1	1	1	...	...	1	1	...	1
18	...	...	...	1	1	2	1	...	3	1	2	1	1	...	2	...	...	2	...	1	...	...	...	...	1	3	2	...	...	...	1	...	1	...
19	...	...	...	3	...	1	2	2	2	3	1	1	1	4	...	...	...	...	...	...	2	...	...	...	...	...	...	...	...	1	...	...	...	...
20	...	...	3	6	3	4	5	7	3	2	3	...	3	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...
21	...	...	2	...	5	3	1	...	1	1	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
22	...	2	2	...	1	...	...	...	...	...	...	1	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
23	...	3	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
24	1	2	2	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
25	...	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
26	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
27	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
28	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
29	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
30	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
31	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Averages.	27.7	23.8	21.7	19.5	20.5	19.8	20.1	19.5	19.0	18.2	18.1	17.3	17.6	17.8	16.4	16.7	15.1	15.4	15.4	14.8	14.0	11.9	14.3	13.5	14.7	15.3	14.8	14.0	14.5	17.5	14.5	15.8	13.7	13.7

[o] = 16.9 a = 21.3
[ot] = − 74.82 b = − 0.089
[t] = 49 t = 99
[t^2] = 839.35

were all above 20 (see TABLE 42) and the range had shifted to decidedly higher values than had previously appeared. One plant gave a rather low value of *a*, 16.9. The complete sterility of all but one of these plants prohibited the study of selection for high or low values in uniparental offspring. The very prevalent cross-incompatibility also limited the possibility of testing such selection in biparental heredity. However, crosses were made from which six different progenies were grown in 1916.

TABLE 42

DISTRIBUTION OF VALUES OF FLOWER NUMBER OF FIRST DAY OF BLOOM (*a*) FOR THE VARIETY RED-LEAVED TREVISO. DATA FOR 1913, 1914, 1915, AND 1916

Series	Distribution of values of *a*																				Number of individuals	Average *a* of series	σ of series	*a* of parents
	14.5	15.0	15.5	16.0	16.5	17.0	17.5	18.0	18.5	19.0	19.5	20.0	20.5	21.0	21.5	22.0	22.5	23.0	23.5	24.0				
1913	..	..	..	..	..	..	1	..	..	..	..	1	..	..	..	..	..	..	..	..	2	18.5	—	—
1914	..	..	..	..	..	..	..	..	..	1	1	4	2	1	..	..	..	..	..	..	9	19.8	±0.67	19.5 17.4
1915																								
R$_{1,2,3}$	..	..	..	..	..	..	..	..	..	..	1	1	1	1	2	2	1	..	..	..	9	20.8	±0.99	19.5 19.7^2
R$_4$	..	..	..	..	..	1	..	..	..	..	1	..	1	1	1	..	1	1	1	..	8	20.8	±2.15	19.8^1 19.9
R$_5$	..	..	..	..	..	..	..	..	1	1	2	2	5	1	..	3	1	1	1	1	19	20.6	±1.56	19.8^1 19.7^2
1916																								
R$_7$	..	..	..	..	..	..	..	3	..	2	..	2	3	..	..	1	1	..	..	..	12	19.5	±1.52	no data
R$_8$	..	1	..	..	2	..	3	1	2	1	1	1	4	1	..	..	..	..	..	..	17	18.4	±1.79	19.0 19.8
R$_9$	..	..	..	..	..	1	3	5	2	3	2	3	3	..	..	..	..	1	..	..	23	18.6	±1.37	21.7^3 19.2
R$_{10}$	..	..	..	..	..	1	2	..	..	2	..	..	2	2	..	..	..	..	..	..	9	19.0	±1.49	19.0 20.8^4
R$_{11}$	..	..	..	..	1	1	1	1	1	..	2	1	3	5	2	1	1	..	..	..	20	19.7	±1.64	21.7^2 no data
R$_{12}$	..	..	..	..	..	..	..	..	..	..	..	2	6	3	1	4	1	..	..	..	17	20.8	±0.77	21.8^2 22.8

A glance at the results recoreded in TABLE 42 shows that the ranges of values per plant and the averages for the different series are somewhat different. The lowest average of 18.4 ± 1.79 seen in series 8 is lower than the average of the generations grown in the previous two years. The range is also lower. The immediate parents of this series were of lower than average rank, but the offspring average still lower. The highest average (20.8) seen in series 12 is the highest realized in any of the 1916 series and is quite of the average of the previous year. The parents of this series were plants of high values. While the series showed some regression, the variability of ±0.77 was low and the average value of *a* was higher than that of other series from parents of lower value. The results obtained in these two lines suggest that in this variety lines of descent may differ and that such differences may be high or low according to the performance of the ancestry.

TABLE 43

DISTRIBUTION OF VALUES FOR RATE OF DECREASE (*b*) FOR THE VARIETY RED-LEAVED TREVISO. DATA FOR 1913, 1914, 1915, AND 1916

Series	Distribution of values of *b*																					Number of individuals	*b* of parents	Average *b* of series
	+0.010	0.000	−0.010	−0.020	−0.030	−0.040	−0.050	−0.060	−0.070	−0.080	−0.090	−0.100	−0.110	−0.120	−0.130	−0.140	−0.150	−0.160	−0.170	−0.180	−0.190			
1913	..	..	..	..	..	..	..	..	..	..	2	..	..	..	..	..	..	..	..	..	..	2	—	−0.082
1914	..	..	2	..	..	..	..	..	..	2	2	1	..	1	1	..	..	..	..	..	..	9	−0.084 −0.081	−0.075
1915																								
$R_{1,2,3}$	..	..	..	..	..	1	..	..	1	..	1	2	3	1	..	..	..	..	..	..	..	9	−0.072 −0.081[1] −0.086[2]	−0.087
R_4	..	..	..	..	..	..	..	1	1	1	1	1	1	..	2	..	..	..	..	..	..	8	−0.007 −0.086[2]	−0.093
R_5	..	..	..	..	..	..	..	..	..	1	6	2	3	2	1	1	..	1	1	..	1	19	−0.081[1]	−0.110
1916																								
R_7	..	..	..	..	1	2	..	4	3	..	1	..	1	..	..	..	..	..	..	..	..	12	no data	−0.057
R_8	..	1	..	1	1	..	2	3	..	3	2	1	1	2	..	..	..	..	..	..	..	17	−0.059 −0.083 −0.092[3]	−0.051
R_9	..	..	..	..	..	..	3	6	3	3	3	3	..	..	..	1	..	..	1	..	..	23	−0.088 −0.083	−0.075
R_{10}	..	..	..	1	..	..	2	2	1	1	2	..	..	..	..	..	..	..	..	..	..	9	−0.087[4] −0.093[2]	−0.058
R_{11}	..	..	..	..	2	2	1	1	4	4	..	3	2	..	..	1	..	..	..	..	..	20	no data −0.087[4]	−0.071
R_{12}	..	..	..	..	..	..	..	..	5	3	5	..	..	2	1	..	1	..	..	..	..	17	−0.124	−0.086

As shown in TABLE 43 the values of *b* were more variable than the values of *a*. The characteristic performance gave minus values for the rate of change and there was on the whole less variability than was seen in the hybrid generations reported above; here there were no cases of + values, and only one plant in the 0.000 class.

In this variety the branching of laterals was very complete, as shown in PLATE 13, *A* and *B*, and there were, as a rule, rather few heads in clusters such as are shown in PLATE 13, *C* and *D*.

This habit and the abundant branching which result in the production of such large numbers of heads presumably give opportunity for the development of heads of such ultimate laterals as might be suppressed in a less robust growth, as is seen in dwarf races. There should be opportunity to observe, in such a race, the lowest possible range of flower number for the species. The chance for development of partial variability is most favorable. The observations indicate that this is the case. In TABLE 44 are shown the ranges in number per head for all plants studied in this variety. The highest flower number per head extends from 31 to 19 and there were 40 plants out of 144 that had produced some heads with 25 or more flowers.

TABLE 44

RANGE OF FLOWER NUMBER PER HEAD FOR ALL PLANTS OF THE VARIETY RED-LEAVED TREVISO

Number of plants	Maximum flower number	Minimum flower number		Difference between maximum and average minimum
		Range	Average	
1	31	—	7.0	24.0
1	30	—	13.0	17.0
3	28	15–11	13.0	15.0
7	27	13–10	11.4	15.6
11	26	12–7	10.1	15.9
17	25	16–9	12.0	13.0
26	24	14–5	10.7	13.3
27	23	17–6	11.2	11.8
26	22	14–7	10.9	11.1
17	21	14–9	11.1	9.9
6	20	13–10	11.3	8.7
2	19	13–11	12.0	7.0

Furthermore, the low numbers range as low as 5 and in every class grouped together for a particular high number some plants produced one or more heads of eleven or twelve. The plant with the highest number of flowers per head (31) produced heads ranging as low as 7. The complete record of data for this plant is given in TABLE 41.

This variety is characterized by rather wide extremes of partial variability and by high values of *a* and *b*.

V. CHARACTERISTICS OF FLOWER NUMBER IN A HYBRID GENERATION OF A CROSS BETWEEN PLANTS OF RED-LEAVED TREVISO AND A WILD PLANT (A)

The plants of this hybrid generation were all of vigorous vegetative growth. They were scarcely as tall as typical plants of the red-leaved Treviso, but they were more abundantly branched from the base of the main stem. The total number of flower heads averaged about the same as for the red-leaved Treviso.

Data were collected from 50 plants of this generation. For these the range of observed numbers per head extended from 28 to 10 (TABLE 45). This range is less both for highest and lowest number than in the red-leaved Treviso. The plant with highest number, 28, also gave numbers as low as 11, thus exhibiting in its partial variability almost the entire range observed. For highest numbers alone the individual variability ranged from 28 to 19; for lowest numbers it ranged from 15 to 10. Greater differences exist in the highest numbers than in the lowest, quite as has been noted for other cultures of chicory.

TABLE 45

RANGE OF FLOWER NUMBER PER HEAD OF PLANTS OF THE F1 GENERATION OF THE CROSS BETWEEN RED-LEAVED TREVISO AND A WILD PLANT (*A*)

Number of plants	Maximum flower number	Minimum flower number		Difference between maximum and average minimum
		Range	Average	
1	28	—	11.0	17.0
2	25	15–10	12.5	12.5
2	24	15–12	13.5	10.5
7	23	14–12	12.7	10.3
10	22	15–11	12.7	9.3
12	21	14–11	12.3	8.7
15	20	14–10	11.3	8.7
1	19	—	11.0	8.0

The values *a* and *b* have been computed for 12 plants of this hybrid generation and these are given in TABLE 46. These are sister plants having for seed parent a plant of red-leaved Treviso (*R ser* 1. *no*. 6) whose performance gave a value of 21.5 for *a* and −0.091 for *b*. These values are quite the average for the plants of this race grown in 1916 (see TABLE 42).

As shown in TABLE 46, the values of *a* for these 12 plants ranged from 16.6 to 21.4, with the average at 19.1. All 12 plants gave minus values for *b*.

TABLE 46

VALUES FOR TWELVE F_1 HYBRIDS OF A CROSS BETWEEN A PLANT OF THE RED-LEAVED TREVISO AND A WILD PLANT (*A*)

Pedigree	$[o]$	$[t]$	$[ot]$	$[t^2]$	a	b	t
RA ser. 3—no. 19..........	15.2	48	− 21.58	701.00	16.6	− 0.030	91
“ 13..........	17.0	48	− 15.05	740.21	18.0	− 0.020	91
“ 21..........	17.0	47	− 23.75	781.87	18.4	− 0.029	94
“ 15..........	17.5	52	− 17.89	932.42	18.5	− 0.019	97
“ 9..........	16.6	50	− 34.10	690.03	18.8	− 0.048	90
“ 24..........	17.7	42	− 22.87	611.89	19.2	− 0.036	83
“ 10..........	18.1	52	− 25.35	936.72	19.3	− 0.027	99
“ 8..........	17.4	48	− 34.19	856.32	19.3	− 0.040	97
“ 2..........	19.2	46	− 11.26	675.65	20.0	− 0.017	87
“ 22..........	17.6	48	− 40.51	432.25	20.2	− 0.055	91
“ 16..........	18.2	53	− 39.36	926.86	20.4	− 0.041	103
“ 18..........	17.9	56	− 67.04	1072.15	21.4	− 0.062	110

VI. SELECTION AND HEREDITY: CHARACTERISTICS OF DIFFERENT PROGENIES AND VARIOUS LINES OF DESCENT DERIVED FROM A CROSS BETWEEN A WILD PLANT (*A*) AND PLANTS OF THE VARIETY BARBE DE CAPUCIN

It would seem that the computed value for the first date of bloom (*a*) which is derived from a considerable amount of data obtained during the entire period of growth is the most adequate single value obtainable that is sufficiently characteristic to serve as a basis for judgment of the effects of selection and of heredity. The value of the rate of change (*b*) can also be used as a value for comparisons.

1. GENERAL COMPARISON OF PROGENY WITH IMMEDIATE PARENTS AS TO VALUES OF *a* AND *b*

Whether flower number is directly inherited as such or indirectly inherited through its relation to types of vegetative habit of growth, some clue to the type or degree of heredity may be gained by the comparison of the performance of offspring with the values of the immediate parents.

With the appearance of a few self-fertile plants in the F_1 generation, it was possible to grow self-fertilized lines of descent of uniparental lineage and data from such lines admit of a comparison of performance. On account of the self-sterility of a large number of the various progenies (about 50 per cent.), it was not possible to make extreme + and − selections.

The F_1 generation of the cross wild white-flowered × Barbe de

Capucin was of biparental descent. The summaries for comparison with the immediate parents are given in TABLE 47. The values of *a* for the F_1 are from data collected in the third year of growth and are averaged for all sister plants of a particular cross.

TABLE 47

AVERAGE FLOWER NUMBER FOR FIRST DAY OF BLOOM (*a*) FOR PARENTS AND THEIR F_1 OFFSPRING

Parents			F_1 offspring		Difference between parents and offspring
a	*a*	Average *a*	Number of plants	Average *a*	
C, 21.7	E_{22}, 23.3	22.5	19	21.4	− 1.1
C, 21.7	E_3, 20.7	21.2	15	20.0	− 1.2
A, 19.2	E_{22}, 23.3	21.2	46	20.1	− 1.1
A, 19.2	*C*, 21.7	20.4	7	20.0	− 0.4
A, 19.2	E_3, 20.7	19.9	21	19.5	− 0.4

It is rather striking that while in every case the average of the offspring is below that of the average for the two parents, yet the higher the average of the parents the higher is the average of the offspring. The fact that the average of the offspring is lower than that of the two parents suggests that the immediate parents gave values that are high for the races involved and that the offspring show regression. It will be seen that the difference between the average flower number per head of parent and offspring is the greater the higher the value of the parents. Accordingly, if one used parents with very low flower number, in all probability the offspring would give a somewhat higher average flower number than their parents.

Further and more exact comparison of progeny with immediate parent can be made in the three main lines of uniparental descent constituting the F_2, F_3, and F_4 generations. TABLE 48 presents such data, indicating the pedigree, the distribution for values of *a*, the variability measured by the standard deviation, the value of *a* for the immediate parent, and the standard deviation of the parent series (the series of sister plants to which the particular parent belonged).

A glance down the columns of the frequency distribution shows that the three lines of descent present, on the whole, values that are rather uniform for each line. A comparison of the values of *a* for a series with that of the immediate parent shows a marked agreement. Frequently, inside of a line, the offspring deviate somewhat from the values of the line, or regress toward the average and are hence not in close agreement with the actual value of the parent. There are, however, numerous cases of almost exact agreement.

TABLE 48

DISTRIBUTION OF VALUES OF *a* IN PEDIGREED LINES IN F_1, F_2, F_3 AND F_4 GENERATIONS

Generation	Pedigree	Frequency distribution for values of *a*																		Offspring			Parent	
		14.5	15.0	15.5	16.0	16.5	17.0	17.5	18.0	18.5	19.0	19.5	20.0	20.5	21.0	21.5	22.0	22.5	23.0	Number	Average *a*	σ	*a*	σ of series
F_1	$(A \times E_{22})$ and $(E_{22} \times A)$	..	..	..	..	..	..	3	2	..	1	1	2	1	1	1	1	..	1	14	19.9	±2.07	....	......
F_2	$(A \times E_{22})$*-4-*	..	..	..	..	..	..	..	..	..	1	1	..	3	1	3	1	..	..	10	20.5	±0.92	19.9	±2.07
F_3	" *-4-3-*	..	..	..	..	..	..	..	..	1	1	..	3	3	2	2	..	..	..	12	20.0	±0.94	21.6	±0.92
F_4	" *-4-3-11-*	..	..	..	..	..	..	..	..	..	2	..	2	1	1	2	2	..	..	10	20.4	±1.11	21.4	±0.94
F_3	" *-4-6-*	..	..	..	..	..	..	1	..	1	1	2	..	..	1	..	..	..	..	6	18.9	±1.13	19.4	±2.07
F_4	" *-4-6-3-*	..	..	..	..	..	..	..	..	1	1	2	1	2	1	1	..	..	..	9	19.7	±0.97	20.7	±1.13
F_2	$(A \times E_{22})$*-9-*	..	..	..	..	..	2	..	..	..	1	..	..	..	..	..	..	..	..	3	17.2	±1.19	—	±2.07
F_3	" *-9-4-*	..	..	2	2	4	3	1	2	..	..	..	..	..	..	..	..	..	..	14	16.4	±0.81	—	±1.19
F_4	" *-9-4-4-*	..	..	3	1	2	1	..	2	..	..	..	..	..	..	..	..	..	..	9	16.2	±1.02	16.3	±0.81
	" *-9-4-10-*	..	2	3	3	..	2	..	..	..	..	..	..	..	..	..	..	..	..	10	15.5	±0.62	17.9	±0.81
	" *-9-4-11-*	..	..	1	1	..	1	..	..	1	..	..	..	..	..	..	..	..	..	4	16.7	±1.51	16.5	±0.81
F_3	" *-9-5-*	..	..	1	3	..	6	..	2	1	..	..	..	..	..	..	..	..	..	13	16.6	±0.86	16.5	±1.19
F_4	" *-9-5-1-*	..	..	1	1	..	2	..	..	..	..	..	..	..	..	..	..	..	..	4	16.0	±0.66	16.6	±0.86
	" *-9-5-6-*	..	..	2	2	6	5	7	4	3	..	..	..	..	..	..	..	..	..	29	16.8	±0.82	16.8	±0.86
	" *-9-5-12-*	..	..	..	5	3	10	12	4	1	..	..	..	..	..	..	..	..	..	35	16.9	±0.62	17.7	±0.86
F_2	$(E_{22} \times A)$*-10-*	..	..	2	1	1	3	4	11	3	..	..	..	1	..	..	..	..	..	26	17.3	±0.99	18.8	±1.39
F_3	" *-10-8-*	..	..	..	..	..	..	1	2	3	3	2	1	..	..	..	..	..	..	12	18.3	±0.62	17.7	±0.99
F_4	" *-10-8-14-*	..	..	..	1	1	1	4	4	3	1	..	1	..	..	..	..	..	..	16	17.6	±0.91	18.9	±0.62
	" *-10-8-15-*	..	..	..	..	..	..	1	2	5	2	3	1	1	..	..	..	..	..	15	18.6	±0.69	17.8	±0.62
F_3	" *-10-13-*	..	..	..	..	..	..	4	5	3	3	1	..	..	..	..	..	..	..	16	17.9	±0.59	17.7	±0.99
F_4	" *-10-13-5-*	..	..	..	..	..	5	6	6	2	..	..	..	..	..	..	..	..	..	19	17.3	±0.51	18.3	±0.59
	" *-10-13-12-*	..	..	..	..	..	2	6	6	6	1	2	..	..	..	..	..	..	..	23	17.8	±0.56	18.1	±0.59
	" *-10-13-13-*	..	..	..	1	5	7	9	5	1	..	..	..	..	..	..	..	..	..	28	16.4	±0.66	17.1	±0.59
F_3	" *-10-14-*	..	..	..	..	..	1	2	..	1	..	3	..	..	..	..	..	..	..	7	18.1	±1.15	17.7	±0.99
F_4	" *-10-14-6-*	..	..	..	..	..	1	..	..	3	1	1	1	..	..	..	..	..	..	7	18.4	±0.88	19.2	±1.15

It is also to be noted that there is a decided reduction in variability of various series of F_2, F_3, and F_4 generations over that of parent series of the F_1. For the latter the standard deviation is ±2.07; for the former the values are mostly less than ±1.00.

TABLE 49

DISTRIBUTION OF VALUES OF *b* IN PEDIGREED LINES IN F_1, F_2, F_3, AND F_4 GENERATIONS

Generation	Pedigree	Frequency distribution of values of *b*																						Offspring		*b* of parent
		+0.020	+0.010	0.000	−0.010	−0.020	−0.030	−0.040	−0.050	−0.060	−0.070	−0.080	−0.090	−0.100	−0.110	−0.120	−0.130	−0.140	−0.150	−0.160	−0.170	−0.180	−0.190	Number	Average *b*	
F_1	(A × E_{22}) and (E_{22} × A)	..	..	..	1	1	1	1	1	4	1	2	..	1	..	1	..	..	..	..	..	..	..	14	−0.054	—
F_2	(A × E_{22})*-4-*	..	..	..	..	..	..	..	1	1	1	1	1	..	1	..	3	..	..	1	..	..	..	10	−0.095	−0.066
F_3	" *-4-3-*	..	..	..	..	..	..	1	..	1	1	3	1	1	..	..	..	1	1	1	1	..	..	12	−0.096	−0.120
F_4	" *-4-3-11-*	..	..	..	..	..	..	4	1	1	..	1	1	..	..	..	..	..	..	2	..	..	..	10	−0.071	−0.085
F_3	" *-4-6-*	..	..	..	..	..	..	..	..	1	..	..	2	1	..	..	1	..	..	..	..	..	1	6	−0.103	−0.109
F_4	" *-4-6-3-*	..	..	..	..	..	..	1	..	..	..	3	..	..	..	..	..	1	2	1	..	1	..	9	−0.112	−0.121
F_2	(A × E_{22})*-9-*	..	..	..	..	..	2	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3	−0.028	—
F_3	" *-9-4-*	..	..	1	1	6	1	2	2	..	1	..	..	..	..	..	..	..	..	..	..	..	..	14	−0.024	—
F_4	" *-9-4-4-*	1	..	..	1	3	1	1	..	2	..	..	..	..	..	..	..	..	..	..	..	..	..	9	−0.021	−0.018
	" *-9-4-10-*	..	1	1	4	1	2	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10	−0.009	−0.047
	" *-9-4-11-*	..	..	..	..	..	2	1	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	4	−0.046	−0.016
F_3	" *-9-5-*	..	..	..	1	3	6	1	1	..	..	..	..	1	..	..	..	..	..	..	..	..	..	13	−0.030	−0.028
F_4	" *-9-5-1-*	..	..	..	..	2	1	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4	−0.021	−0.023
	" *-9-5-6-*	..	..	..	..	..	3	9	5	9	2	1	..	..	..	..	..	..	..	..	..	..	..	29	−0.044	−0.033
	" *-9-5-12-*	..	4	6	6	8	9	1	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	35	−0.012	−0.024
F_2	(E_{22} × A)*-10-*	..	..	2	4	8	6	5	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	26	−0.019	−0.029
F_3	" *-10-8-*	..	..	..	..	2	2	4	2	2	..	..	..	..	..	..	..	..	..	..	..	..	..	12	−0.036	−0.019
F_4	" *-10-8-14-*	..	..	..	1	2	3	3	2	1	3	1	..	..	..	..	..	..	..	..	..	..	..	16	−0.039	−0.038
	" *-10-8-15-*	..	..	..	1	..	4	..	2	3	2	..	2	1	..	..	..	..	..	..	..	..	..	15	−0.050	−0.032
F_3	" *-10-13-*	..	..	..	..	1	3	9	3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	16	−0.032	−0.034
F_4	" *-10-13-5-*	..	2	2	3	6	2	3	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	19	−0.013	−0.027
	" *-10-13-12-*	1	1	1	3	4	4	3	2	2	1	..	..	1	..	..	..	..	..	..	..	..	..	23	−0.025	−0.034
	" *-10-13-13-*	1	1	2	3	3	11	5	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	28	−0.021	−0.030
F_3	" *-10-14-*	..	..	..	..	..	..	2	3	2	..	..	..	..	..	..	..	..	..	..	..	..	..	7	−0.045	−0.016
F_4	" *-10-14-6-*	..	..	..	..	1	1	1	1	..	1	..	2	..	..	..	..	..	..	..	..	..	..	7	−0.050	−0.039

The variability of sister plants of a series decreases with line breeding.

The performances of these lines of descent and pedigreed series with respect to rate of change (*b*) are given in TABLE 49.

The frequency distribution is given for classes of 0.010 extent. Here, as for values of flower number for the first day of bloom (*a*) the lines show some noticeable characteristic differences; for line descending from the F_1 plant (*A* × E_{22}) *no. 4* the − values were most in evidence. In the other two lines a considerable number of plants exhibited + values. The heredity of the type of seasonal change is in general indicated by line performances. In respect to immediate parentage, the agreement is less close than for values of flower number. There has been no attempt rigidly to select for various values of rate of change. That the performance is more sporadic for rate of change than for flower number will be further indicated in the study of various races.

2. DETAILED ANALYSIS OF SIX RACES AS TO INHERITANCE OF FLOWER NUMBER PER HEAD

In the F_3 and F_4 generations of the family with the original parentage wild white-flowered (*A*) × Barbe de Capucin (E_{22}), it became evident that the pedigreed breeding in lines had resulted in the development of several types, races, or elementary species which differed from each other most decidedly in habit of growth. This gave opportunity for the study of the flower number in rather widely diverse races. Comparisons can be made with reference to the relation of various habits of growth to performance in flower production. The detailed records of lines of parentage also give opportunity for further analysis of the influence of selection and the degree to which heredity is in evidence.

A. *The history and characteristics of a semi-dwarf, sparsely branched race* (*race 1, or line* (*A* × E_{22})*−4–3−*). In mature development for the first year of growth this race was characterized by low stature (1 1/2 to 2 1/2 feet tall) and by a sparse and coarse branching habit. The branches were very brittle, and there was a very general death of the branches due to susceptibility to a bacterial or fungous disease. The death of the tips of the branches added considerably to the dwarf-like appearance and decreased the total number of flower heads that came to bloom. Twelve plants of the F_3 and thirty-one plants of the F_4 of this race were quite uniform in the general vegetative habit of growth. In the rosette stages, however, the plants which later made smallest growth were decidedly dwarfed. The general habit of this race is well shown in PLATE II, which also shows the effects of the tip-rot.

TABLE 50

STATISTICAL CONSTANTS (DISCUSSED PAGES 380–385) FOR TWO GENERATIONS (F_3 AND F_4) OF A SEMI-DWARF, SPARSELY BRANCHED RACE (RACE I) WITH THOSE FOR THE IMMEDIATE ANCESTRY

	Pedigree	[o]	[t]	[ot]	$[t^2]$	a	b	t
Ancestry	F_1. $(A \times E_{22})$							
	no. 4	18.5	21	−10.22	150.33	19.9	−0.066	41
	F_2. $(A \times E_{22})$–4–							
	no. 9	17.6	26	−13.18	296.63	18.7	−0.044	58
	" 6	18.3	10	− 5.56	50.00	19.4	−0.109	22
	" 7	17.9	18	−17.72	145.92	20.1	−0.121	35
	" 8	18.2	14	−10.52	71.40	20.3	−0.153	27
	" 4	17.9	19	−19.82	155.54	20.4	−0.127	41
	" 1	18.1	40	−36.47	538.60	20.9	−0.068	77
	" 2	19.6	20	−13.81	181.87	21.0	−0.073	41
	" 5	19.8	28	−12.39	289.55	21.2	−0.056	55
	" 10	19.7	21	−15.89	196.53	21.4	−0.083	42
	" 3	19.3	19	−18.45	148.85	21.6	−0.120	37
Race I.	F_3. $(A \times E_{22})$–4–3–							
	no. 6	17.0	23	−10.32	205.13	18.2	−0.052	47
	" 9	17.0	18	−19.54	141.36	18.6	−0.142	38
	" 10	17.5	33	−17.95	297.95	19.5	−0.060	63
	" 8	18.4	15	−10.40	105.69	19.8	−0.096	33
	" 7	17.9	14	−12.90	78.78	20.2	−0.163	31
	" 1	19.8	14	− 1.91	92.00	20.2	−0.031	35
	" 2	19.1	15	− 7.75	98.82	20.3	−0.077	37
	" 12	18.3	33	−29.45	400.21	20.7	−0.074	68
	" 3	18.9	14	−11.23	82.29	20.7	−0.132	34
	" 4	19.1	24	−18.47	235.71	21.0	−0.078	55
	" 5	18.7	15	−18.45	116.38	21.1	−0.158	40
	" 11	18.6	33	−34.12	403.09	21.4	−0.085	71
	F_4. $(A \times E_{22})$–4–3–11–							
	no. 18	17.8	25	− 8.40	269.89	18.6	−0.031	60
	" 15	16.8	25	−26.26	337.00	18.8	−0.079	58
	" 3	18.0	34	−24.22	498.08	19.7	−0.049	75
	" 20	18.8	31	−13.72	432.56	19.8	−0.032	69
	" 25	18.2	25	−24.23	298.39	20.2	−0.081	59
	" 41	19.7	33	−12.72	372.00	20.8	−0.034	65
	" 21	19.3	29	−18.49	318.25	21.0	−0.057	56
	" 9	20.2	28	− 9.29	288.10	21.2	−0.034	55
	" 8	19.4	16	−15.55	98.62	21.9	−0.156	33
	" 24	19.4	16	−15.38	97.75	21.9	−0.156	31

A most characteristic feature of flower number per head in this race, as seen in F_3 and F_4, is its high value. The average number (TABLE 50) per head [*o*] is high, which indicates that heads with high flower number were strongly in evidence. There was a pronounced tendency to produce some heads with extra high numbers. In the F_3 series $(A \times E_{22})-4-3-$ of 12 plants there were six plants, having some heads of 24 or more flowers (see TABLE 51). One plant (no. 12) produced a head of 33 flowers, other plants had heads of 27, 26, and 25 flowers. For the F_4 crop of 31 plants data were collected from 10 plants that were least affected by the tip-rot. These, likewise, showed a tendency to produce a few heads with unusually high numbers per head: seven of the ten plants had some heads with 24 or more flowers each. For no plant was the highest number less than 21. The minimum number in any head for these plants, however, was quite as low as that ordinarily observed. In this race irregular and sporadic variations in partial intra-annual variability occurred, giving a few heads with high numbers. The lowest values realized in a plant during a season were, however, quite or almost as low as were seen in series having no such high numbers.

TABLE 51

RANGE OF VARIABILITY OF FLOWER NUMBER PER HEAD OF ONE-YEAR-OLD PLANTS OF THE F_3 AND F_4 GENERATIONS OF RACE I

Number of plants	Maximum flower number	Minimum flower number		Difference between maximum and average minimum
		Range	Average	
F_3. $(A \times E_{22})$-4-3-				
1	33	—	12.0	22.0
1	27	—	13.0	14.0
1	26	—	12.0	14.0
1	25	—	15.0	10.0
2	24	13–11	12.0	12.0
3	23	15–10	11.7	11.3
2	22	—	14.0	8.0
1	21	—	13.0	8.0
F_4. $(A \times E_{22})$-4-3-11-				
1	26	—	12.0	14.0
3	25	15–11	13.3	11.7
3	24	16–13	14.3	9.7
2	23	15–11	13.0	10.0
1	22	—	12.0	10.0

The general tendency in this race, however, is toward high numbers per head. The values for [*o*] and for *a* computed from all the data are consistently high. In respect to seasonal change, all plants of this race exhibited a marked decrease, as may be seen in the values of *b* given in TABLE 50. The performance with respect to terminals and laterals was quite as is most typical of the species.

The record of pedigree for the two series (F_3 and F_4) of this race shows that the descent has been consistently from the plants having highest values of a. For the parent of the F_4 series (which was $(A \times E_{22})-4-3-no.\ 11$), the value of a was 21.4, which was the highest of the series. The parent in the F_2 was plant $(A \times E_{22})-4-no.\ 3$; the value of a for it was 21.6, also the highest of the series. The value of a for the F_1 plant used as a parent was 19.9. The values of a for the two original parents was as follows: for the wild white-flowered plant A, 19.2 in 1913 and 19.3 in 1914; for the plant of Barbe de Capucin, E_{22}, 23.0 in 1913 and 23.6 in 1914 (these values are of slightly higher relative value as the plants are older than one year).

The race is, therefore, one of high average values, the average of a being above 20.0. Selection for high values of a has maintained a high average. The race has shown a strong tendency to irregular sporadic partial variability in that high numbers of flowers are frequently developed in a few heads.

B. *The history and characteristics of a dwarf, sparsely branched race (race 2 or line* $(A \times E_{22})-4-6-$). At the extreme right foreground of PLATE 11 are shown several characteristic plants of this very decidedly dwarfed race. In general habit of growth and susceptibility to the tip-rot this race is quite like the semi-dwarf just described. It is, however, of much smaller stature and is less branched. Nine plants of the F_3 and twenty of the F_4 have been quite uniform in general appearance when mature. Statistical data on flower number were taken from six plants of the F_3 and from nine plants of the F_4, these plants being the ones least injured by the tip-rot.

In agreement with the extremely dwarf habit, the total number of heads produced by these plants is low, the average for the nine plants studied of the F_4 being 95 for the entire season of growth. This dwarf race is a sister race of race 1, noted above, in that the two descended from the same F_1 plant $(A \times E_{22})$ *no. 4*. The number of heads open in any one day was so low that on only one date were 10 heads open in a single day on any of the 1916 crop. The period of bloom was somewhat shortened.

The highest flower number for any head was 22 and the lowest was 12. There was no tendency to the production of extremely high numbers per head for a few heads, as seen in the semi-dwarf race; the values of [*o*] and *a* average slightly lower (TABLES 52 and 48).

All plants of the race showed a seasonal decrease ($-b$) with the characteristic relation of laterals and terminals.

The ancestry of this race diverged from that of the semi-dwarf race in that the F_2 parent selected was a different plant (no. 6) having somewhat lower values of *a* (19.4) and of [*o*] (18.3). The selection for this race has not been consistently for lowest values of *a*, as the plant of the F_3 used as parent $(A \times E_{22})-4-6-no.\ 3)$ was the one having highest values for *a*. The F_4 has shown an increase of average of *a* over that of the preceding generation.

TABLE 52

STATISTICAL CONSTANTS FOR TWO GENERATIONS (F_3 AND F_4) OF A DWARF, SPARSELY BRANCHED RACE (RACE 2). ANCESTRY GIVEN IN TABLE 50

Pedigree	[*o*]	[*t*]	[*ot*]	[t^2]	*a*	*b*	*t*
F_3. $(A \times E_{22})$–4–6–							
no. 4	16.4	12	− 5.26	68.53	17.4	−0.081	29
" 8	17.1	17	− 9.89	183.26	18.1	−0.055	51
" 5	16.1	26	−36.07	355.68	18.7	−0.099	68
" 10	16.7	32	−36.12	471.30	19.2	−0.077	70
" 1	16.6	14	−16.50	89.29	19.2	−0.183	39
" 3	18.0	22	−31.01	255.64	20.7	−0.121	48
F_4. $(A \times E_{22})$–4–6–3–							
no. 17	17.6	14	− 3.70	92.50	18.1	−0.039	29
" 1	18.1	10	− 3.26	41.57	18.9	−0.079	19
" 16	18.2	12	− 3.40	45.88	19.1	−0.076	21
" 3	17.9	17	− 9.43	131.46	19.1	−0.071	36
" 2	16.8	22	−26.88	205.77	19.7	−0.134	45
" 11	17.7	16	−12.69	90.50	20.0	−0.141	30
" 15	17.6	17	−17.94	113.25	20.3	−0.157	34
" 21	18.2	16	−13.63	97.17	20.5	−0.141	32
" 23	18.6	16	−17.03	100.55	21.3	−0.171	31

The performance of this race indicates that extreme dwarfing in chicory affects decidedly the total number of heads produced, but has no pronounced effect in reducing the average number of flowers per head or in changing the general character of intra-seasonal partial variability as exhibited by minus values of *b*.

C. *Characteristics of a race exhibiting a second period of growth during a single season* (*race 3 or line* $(A \times E_{22})-9-5-$). The peculiar and unusual habit of growth seen in this race has already been described and reference made to the illustration (TEXT-FIGURE 1). Detailed data for three plants of this race have also been presented (TABLES 31, 32, and 33) and discussed as illustrating (1) increase in flower number per head during a period of growth and (2) the fact that values for the second period of growth are lower than those for the first.

For judgment of the general performance of this race, there are data for 35 sister plants and for 15 of these there are also data from the growth of the second period, all of which are given in TABLE 53.

For the period of first growth, it is seen that values for *a* range from 15.5 to 18.3 with an average of 16.9 ± 0.62. The values are very uniform and are decidedly low when compared with those of the semi-dwarf race (race no. 1) considered above. The most decided variability of this race is seen in values of rate of change in flower number; these range from −0.048 to +0.018. These differences in rate of change did not seem to involve any differences in vegetative habit of growth, in the grouping of flower heads in clusters, or in the total number of heads produced.

Reference has already been made to the general performance of the growth of the second period and to the evidence that the values for such growth are as a whole lower than those of the earlier growth.

In its ancestry, this race descended from an F_1 plant {$(A \times E_{22})$ *no. 9*} from which no data were obtained.

For the parent selected for the F_3, $(A \times E_{22})$*–9–no. 5*, the value of *a* was 16.5 and that of *b* was −0.022. The parent of the F_4, $(A \times E_{22})$*–9–5–no. 12*, was one of 13 sister plants whose values for *a* ranged from 15.2 to 18.0, averaging 16.6 with a standard deviation of ±0.86; its *a* value was 17.7 (high for the generation) and its *b*, −0.024.

As to value of *a*, the line of parentage has therefore exhibited rather *medium* values.

Considering the value of *a* for the first period of growth, the values are quite characteristic for the line of descent as a whole (TABLES 27 and 53).

D. *Characteristics and history of a semi-robust brittle-stemmed race (race 4).* The plants of this race are coarsely and somewhat sparsely branched, the branches are thick and very brittle and bear such small leaves as to appear almost leafless. The thirty

TABLE 53

STATISTICAL CONSTANTS FOR ONE GENERATION (F_4) OF A RACE EXHIBITING A SECOND PERIOD OF GROWTH DURING A SINGLE SEASON (RACE 3) WITH THOSE FOR THE IMMEDIATE ANCESTRY. FOR FIFTEEN PLANTS OF RACE 3 CONSTANTS FOR THE SECOND PERIOD OF BLOOM ARE INDICATED IN ITALICS AND ARE GIVEN DIRECTLY BELOW THE VALUES FOR THE FIRST PERIOD OF BLOOM

	Pedigree	$[o]$	$[t]$	$[ot]$	$[t^2]$	a	b	t
Ancestry	F_2. $(A \times E_{22})-9-$							
	no. 5	15.9	26	− 6.88	327.38	16.5	−0.022	58
	3	15.9	50	−32.47	992.07	16.6	−0.033	113
	1	17.1	54	−31.61	1140.28	18.6	−0.027	115
	F_3. $(A \times E_{22})-9-5-$							
	no. 11	14.4	30	− 8.50	318.00	15.2	−0.027	60
	" 3	14.6	32	− 9.90	412.00	15.5	−0.027	70
	" 5	15.5	40	− 5.28	625.42	15.8	−0.008	84
	" 9	15.1	49	−14.78	935.97	15.8	−0.015	107
	" 7	15.7	31	−11.20	364.38	16.6	−0.029	65
	" 1	15.9	32	− 8.78	378.24	16.6	−0.023	66
	" 4	16.0	30	− 7.22	397.15	16.6	−0.019	75
	" 13	15.9	50	−15.47	946.32	16.7	−0.016	108
	" 10	15.6	44	−20.35	799.37	16.8	−0.027	97
	" 6	15.8	30	−11.02	340.85	16.8	−0.033	64
	" 2	15.3	25	−24.29	244.74	17.7	−0.097	52
	" 12	16.5	51	−24.60	981.17	17.7	−0.024	109
	" 8	16.5	37	−26.59	674.92	18.0	−0.041	93
Race 3	F_4. $(A \times E_{22})-9-5-12-$							
	no. 35	14.6	34	−10.00	392.83	15.5	−0.026	71
	" 18	15.9	32	+ 3.81	411.35	15.6	+0.009	69
	" 9	16.0	34	+ 4.90	381.09	15.6	+0.013	64
	" 24	15.2	27	− 4.19	244.83	15.7	−0.017	51
		14.9	*19*	*+ 0.05*	*119.32*	*14.9*	*0.000*	*37*
	" 15	15.7	35	− 2.36	429.14	15.9	−0.006	69
		15.0	*22*	*+ 2.17*	*107.57*	*14.6*	*+0.020*	*39*
	" 38	15.4	33	−10.75	412.33	16.0	−0.027	68
		15.2	*19*	*− 1.44*	*118.69*	*15.4*	*−0.013*	*40*
	" 30	15.3	30	−10.29	356.32	16.2	−0.029	63
		14.9	*16*	*+ 2.12*	*87.46*	*14.5*	*+0.025*	*33*
	" 32	15.9	37	− 5.91	480.28	16.3	−0.012	75
	" 16	17.0	33	+ 7.94	435.79	16.4	+0.018	77
	" 17	16.5	33	+ 0.56	434.00	16.5	+0.001	65
		15.2	*19*	*− 3.12*	*94.32*	*15.8*	*−0.003*	*37*
	" 21	15.9	27	− 7.21	274.21	16.6	−0.026	52
	" 10	16.2	26	− 5.41	274.67	16.7	−0.019	61
		15.6	*18*	*− 0.30*	*129.69*	*15.6*	*−0.002*	*40*
	" 2	16.7	39	− 0.44	448.50	16.7	−0.001	75
	" 22	16.6	28	− 2.98	335.83	16.8	−0.008	63
	" 33	16.8	27	+ 0.23	259.05	16.8	+0.001	53
		14.9	*19*	*+ 0.05*	*101.83*	*14.9*	*+0.001*	*35*
	" 12	16.7	26	−13.33	277.80	16.9	−0.048	55
	" 6	16.7	26	+ 2.79	271.55	16.9	+0.009	54
		14.9	*19*	*+ 1.64*	*142.33*	*15.1*	*+0.001*	*42*
	" 37	17.3	35	+ 4.32	435.13	16.9	+0.010	72
	" 19	15.9	38	−18.22	610.59	17.0	−0.029	83
	" 31	16.1	29	− 7.90	246.40	17.0	−0.032	57
		15.1	*19*	*− 0.34*	*123.00*	*15.2*	*−0.003*	*40*

TABLE 53—*Continued*

	Pedigree	[*o*]	[*t*]	[*ot*]	[t^2]	*a*	*b*	*t*
Race 3	" 20	16.8	34	− 2.74	446.79	17.0	−0.006	72
		16.9	37	+ 1.27	482.38	17.0	+0.003	73
	" 3	*15.3*	*18*	*+ 1.16*	*124.00*	*15.1*	*+0.010*	*42*
		16.8	31	− 3.27	363.86	17.1	−0.009	62
	" 7	*15.4*	*19*	*− 1.74*	*133.40*	*15.6*	*−0.013*	*40*
		16.6	33	− 8.75	405.17	17.3	−0.022	61
	" 11	*15.3*	*19*	*+ 2.27*	*128.28*	*15.9*	*−0.019*	*40*
	" 5	16.8	26	− 5.37	277.80	17.3	−0.019	54
		17.2	36	− 1.99	459.27	17.3	−0.004	70
	" 14	*15.8*	*19*	*− 4.67*	*73.89*	*15.9*	*−0.006*	*33*
	" 27	17.5	34	+ 0.54	409.71	17.4	+0.002	71
	" 4	17.1	37	− 3.57	531.48	17.4	−0.007	76
		16.9	34	− 6.12	410.44	17.4	−0.015	68
	" 1	*15.7*	*19*	*+ 1.92*	*134.24*	*16.0*	*+0.014*	*41*
		16.7	27	− 6.95	261.05	17.4	−0.026	55
	" 34	*15.4*	*19*	*+ 0.08*	*127.83*	*15.4*	*−0.001*	*40*
	" 13	17.0	35	− 9.91	548.54	17.6	−0.018	74
	" 23	16.9	35	−10.58	437.52	17.7	−0.024	69
	" 26	17.2	37	− 4.98	471.08	17.8	−0.015	74
	" 29	17.0	39	−12.02	539.00	17.9	−0.022	79
	" 8	17.7	36	− 7.48	463.08	18.3	−0.016	72

mature plants of the F_4 series ranged from 24 to 36 inches in height. This series of plants are shown in PLATES 10 and 11, field no. 53. The habit of growth differs from that of the first growth of race 3 in being less abundantly branched; although maturing early there was no tendency to the development of a new and second period of growth except in one plant.

The values for twenty-nine plants of this race are given in TABLE 54. Values of *a* range from 15.2 to 18.2 and average 16.8 with a standard deviation of ±0.82.

The pedigree of this race is almost identical with that of race 3. The immediate parents are two sister plants which differed only slightly in value of *a*.

The rather uniform values obtained are in harmony with the uniformity in habit of growth and general vigor seen in this series. The low values which characterize the series are quite identical with those of the immediate parent and constitute an excellent illustration of the general results that the offspring of parents with low flower values also tend to give low values.

E. *Characteristics and history of a semi-dwarf bushy race (race 5).* This race is decidedly different from any other that has been isolated thus far. The rather small stature and very bushy habit of growth are well shown in PLATE 10, which is from a photograph of a row of sister plants of the F_3 generation. The numerous branches are slender and tough. The mature height of these plants in the first year of growth ranged from 26 to 32 inches and in the second year (12 plants living) none exceeded 36 inches in height.

TABLE 54

STATISTICAL CONSTANTS FOR ONE GENERATION (F_4) COMPRISING TWO SERIES OF A SEMI-ROBUST, BRITTLE-STEMMED RACE (RACE 4). CONSTANTS FOR IMMEDIATE ANCESTRY GIVEN IN TABLE 53

Pedigree	$[o]$	$[t]$	$[ot]$	$[t^2]$	a	b	t
F_4. $(A \times E_{22})$–9–5–1–							
no. 1	15.2	34	− 4.47	390.52	15.8	−0.011	66
" 3	15.5	33	− 5.27	371.17	15.8	−0.014	64
" 2	15.6	39	−11.31	488.31	16.5	−0.023	72
" 4	15.4	36	−13.02	431.28	16.6	−0.034	70
F_4. $(A \times E_{22})$–9–5–6–							
no. 1	14.5	14	− 5.28	106.17	15.2	−0.051	37
23	15.7	23	− 5.66	198.82	15.4	−0.029	47
" 2	14.9	30	− 8.19	371.41	15.6	−0.022	63
" 3	15.0	20	− 6.45	167.33	15.8	−0.039	41
" 25	14.9	20	− 8.48	153.29	16.0	−0.055	40
" 6	15.2	24	− 8.21	230.94	16.0	−0.035	49
" 29	14.9	32	−14.88	371.17	16.1	−0.039	64
" 12	15.2	29	−11.30	305.15	16.2	−0.033	58
" 31	15.2	24	−10.78	216.41	16.4	−0.052	49
" 22	15.6	32	−10.57	408.91	16.4	−0.025	67
" 16	15.4	26	−10.56	243.67	16.5	−0.043	51
" 8	15.1	28	−13.56	261.74	16.5	−0.051	55
" 19	15.7	27	−10.49	287.75	16.7	−0.037	57
" 21	15.8	24	− 9.72	236.94	16.8	−0.041	49
" 9	15.5	33	−16.61	411.96	16.8	−0.039	68
" 17	15.9	27	−10.76	271.68	17.0	−0.039	55
" 24	15.1	39	−24.19	481.92	17.1	−0.050	69
" 27	15.9	35	−13.59	398.92	17.1	−0.034	65
" 26	15.8	29	−17.74	408.77	17.1	−0.044	69
" 11	15.5	33	−21.12	403.22	17.2	−0.052	65
" 4	15.8	28	−23.06	439.67	17.3	−0.052	68
" 13	16.3	27	−11.87	289.10	17.4	−0.040	57
" 5	15.6	26	−19.69	271.95	17.5	−0.073	55
" 28	16.3	39	−13.15	440.88	17.5	−0.030	70
" 20	16.0	37	−16.31	386.27	17.6	−0.042	61
" 10	15.9	36	−25.88	495.46	17.8	−0.052	72
" 7	16.4	26	−15.93	157.50	18.1	−0.065	51
" 15	16.8	27	−15.23	287.75	18.2	−0.053	56
" 18	16.8	21	−11.81	181.31	18.2	−0.065	43

Full data for the performance of the series $(E_{22} \times A)$ – *10–13* – are given in TABLE 55. The values of *a* range from 17.1 to 19.1 with an average of 17.9 with a standard deviation of ±0.59. For all plants the rate of change was a minus value. The rather limited individual variability is quite in accord with the very marked uniformity of vegetative habit. It may be noted that the immediate seed parent of the F_3 series gave a value of *a* at 17.7, which was slightly above the average of the series to which it belonged. In fact the F_2 series $(E_{22} \times A)-10-$ showed a tendency to low values, the range dropping to 15.3 (see TABLE 48). The values of the F_3 therefore average somewhat higher and there is less variability among individuals.

Three plants of this F_3 series were selected as seed parents for the F_4 generation. The plants of all three series were quite uniform in the vegetative habit of the race, as will be seen in PLATE 10, to the left, to the foreground, and to the right of field no. 49. The series to the right, however, was late in maturing and the photograph does not show the mature branching.

The three F_4 series of this race were derived from sister plants differing imperceptibly in vegetative habit. In regard to the values of *a*, however, one parent (no. 13) gave the lowest value (17.1) of the F_3; the other two exhibited values slightly above the average.

The F_4 offspring of the parent selected for lowest value among the F_3 of this line gave a range for values of *a* of 15.1 to 17.7 with an average of 16.4 and a standard deviation of ±0.66. The mode has shifted to lower values than were seen in any generation of ancestry. The range, however, was not extended to values lower than some realized in the F_2 (TABLE 48).

The characteristics of the other two series were quite identical. The range of one is from 16.6 to 19.3, the average 17.8, and standard deviation ± 0.56, while values for the other range from 16.5 to 18.4, with an average 17.3 and standard deviation ±0.51. These values agree quite closely with the average values seen in the F_3 from which the series descended. The immediate parents were only slightly higher.

The results here obtained demonstrate that pedigreed line breeding from different parents of a race which itself appears very uniform in the F_3 may isolate strains that are slightly different in performance, the selection for lowest value especially giving a strain in which the range is decidedly shifted.

F. *Characteristics and history of a tall-growing race* (*race 6*). This race was isolated or segregated in the F_3 generation. In

TABLE 55

STATISTICAL CONSTANTS FOR TWO GENERATIONS (F_3 AND F_4) COMPRISING FOUR SERIES OF A SEMI-DWARF, BUSHY RACE (RACE 5) WITH THOSE FOR LINE OF IMMEDIATE PARENTAGE. VALUES OF *a* AND *b* FOR ANCESTRY GIVEN IN TABLES 48 AND 49

Pedigree	[*o*]	[*t*]	[*ot*]	[t^2]	*a*	*b*	*t*
F_1. $(E_{22} \times A)$–*10*–2 yrs. old	17.9	41	−22.86	542.12	19.7	−0.043	77
F_2. $(E_{22} \times A)$–*10*–							
no. 13	17.0	22	− 5.34	166.76	17.7	−0.034	44
F_3. $(E_{22} \times A)$–*10*–*13*–							
no. 13	15.9	40	−21.75	713.88	17.1	−0.030	97
" 4	16.0	56	−27.41	1181.71	17.3	−0.023	119
" 1	16.1	54	−23.74	1060.71	17.3	−0.023	110
" 11	15.9	37	−23.07	544.28	17.4	−0.041	78
" 7	16.7	27	−10.03	328.61	17.5	−0.031	63
" 8	16.1	45	−22.62	759.41	17.5	−0.030	92
" 10	16.2	47	−27.06	933.57	17.6	−0.029	98
" 3	16.7	56	−23.24	1116.00	17.8	−0.020	115
" 9	16.2	51	−28.54	929.18	17.8	−0.031	105
" 12	16.6	43	−25.02	725.58	18.1	−0.034	89
" 16	16.8	44	−23.83	750.45	18.2	−0.032	90
" 5	17.4	34	−13.49	493.52	18.3	−0.027	78
" 6	17.1	45	−23.72	693.63	18.5	−0.035	98
" 17	16.1	54	−50.70	1160.97	18.5	−0.044	113
" 2	16.7	47	−37.10	795.68	18.8	−0.046	97
" 15	17.4	48	−33.52	950.12	19.1	−0.035	101
F_4. $(E_{22} \times A)$–*10*–*13*–*12*–							
no. 20	17.0	25	+ 4.23	239.37	16.6	+0.017	51
" 19	17.0	28	+ 1.46	299.62	16.9	+0.005	56
" 25	16.7	30	− 3.86	397.13	17.0	−0.009	68
" 10	16.9	30	− 0.24	380.76	17.0	−0.002	61
" 15	16.9	27	− 3.12	282.00	17.2	−0.011	54
" 23	16.7	21	− 7.24	240.65	17.3	−0.029	49
" 13	17.3	27	− 0.59	299.29	17.4	−0.002	56
" 8	17.0	21	− 2.91	172.69	17.4	−0.017	43
" 12	17.2	22	− 5.77	477.78	17.5	−0.012	65
" 18	16.7	36	−13.29	521.08	17.6	−0.026	73
" 17	18.0	16	+ 2.40	106.75	17.6	+0.023	35
" 2	16.8	32	−11.83	366.66	17.8	−0.032	64
" 6	16.8	30	−10.81	333.69	17.8	−0.033	63
" 14	17.1	31	− 9.51	355.05	17.9	−0.026	63
" 5	17.4	30	− 6.61	338.73	18.0	−0.019	62
" 3	17.4	27	− 5.93	279.30	18.0	−0.021	57
" 1	16.9	26	−11.89	284.55	18.0	−0.042	56
" 16	17.3	24	− 7.43	217.67	18.1	−0.034	49
" 7	16.8	24	−14.34	247.11	18.2	−0.058	51
" 11	16.8	22	−12.65	187.75	18.3	−0.067	44
" 22	17.6	23	− 9.04	215.06	18.6	−0.042	48
" 4	17.8	21	− 8.55	162.27	19.0	−0.052	41
" 21	16.8	27	− 9.73	107.60	19.3	−0.091	55
F_4. $(E_{22} \times A)$–*10*–*13*–*13*–							
no. 12	15.2	34	+ 1.31	438.25	15.1	+0.003	69
" 36	15.4	32	− 1.69	398.61	15.5	−0.004	64
" 27	15.4	35	− 2.39	433.63	15.6	−0.005	69
" 15	15.7	24	+ 0.97	264.00	15.6	+0.003	50
" 26	15.6	35	− 1.62	441.13	15.7	−0.004	70
" 33	16.5	24	+ 5.72	234.06	15.9	+0.025	50

TABLE 55—*Continued*

Pedigree	[*o*]	[*t*]	[*ot*]	[t^2]	*a*	*b*	*t*
" 5	15.3	32	− 7.99	361.00	16.0	−0.023	62
" 2	15.6	32	− 6.20	360.50	16.1	−0.014	61
" 9	15.5	29	− 6.93	334.20	16.1	−0.020	64
" 22	15.7	32	− 5.87	428.95	16.1	−0.014	68
" 30	15.0	35	−16.60	559.60	16.1	−0.029	76
" 34	16.6	34	+ 5.46	389.39	16.1	+0.014	66
" 11	15.6	31	− 7.76	336.38	16.3	−0.023	64
" 19	16.0	30	− 6.04	343.53	16.5	−0.018	61
" 35	15.5	34	−12.68	447.67	16.5	−0.028	67
" 17	15.9	30	− 7.95	400.73	16.5	−0.020	67
" 16	16.1	27	− 6.29	278.00	16.7	−0.023	71
" 21	15.5	33	−15.52	418.43	16.7	−0.037	70
" 28	15.7	40	−16.28	603.04	16.8	−0.027	82
" 18	16.1	33	−12.15	548.20	16.8	−0.022	71
" 7	15.8	31	−12.92	406.85	16.8	−0.032	65
" 8	15.6	33	−16.75	421.09	16.9	−0.039	68
" 4	15.9	37	−16.40	502.00	17.1	−0.033	77
" 20	16.2	31	− 9.58	334.57	17.1	−0.029	62
" 24	16.5	23	− 6.62	217.29	17.2	−0.029	48
" 6	15.8	30	−20.22	411.55	17.3	−0.049	71
" 1	15.5	39	−25.06	555.44	17.3	−0.045	76
" 32	16.4	33	−16.25	420.00	17.7	−0.039	67
F$_4$. ($E_{22} \times A$)-*10-13-5-*							
no. 41	16.9	23	+ 3.97	211.29	16.5	+0.019	48
" 23	16.5	31	− 0.38	347.09	16.6	−0.002	60
" 16	16.6	27	+ 0.59	310.86	16.6	+0.001	56
" 30	16.5	28	− 2.85	286.90	16.8	−0.010	54
" 5	16.5	24	− 4.22	228.67	16.9	−0.018	50
" 25	16.6	27	− 3.33	258.21	17.0	−0.013	58
" 24	17.0	25	− 0.79	263.21	17.1	−0.005	53
" 39	16.4	26	− 8.03	285.70	17.1	−0.028	54
' 1	17.4	27	+ 2.54	317.73	17.2	+0.007	58
' 27	16.3	25	− 9.66	306.74	17.2	−0.036	56
" 6	17.0	28	− 4.24	311.48	17.4	−0.014	55
" 13	17.0	30	− 5.95	321.76	17.5	−0.017	62
" 12	17.2	25	− 3.81	326.67	17.5	−0.012	58
" 11	17.6	31	+ 5.07	348.04	17.5	+0.015	64
" 8	16.8	31	− 5.75	272.32	17.5	−0.021	60
" 37	17.3	31	− 3.26	371.17	17.6	−0.009	54
" 22	17.0	21	− 6.38	188.35	17.7	−0.034	43
" 33	17.2	28	−11.20	336.28	18.2	−0.034	58
" 31	17.3	25	−11.54	266.21	18.4	−0.043	54

this race there is a vigorous development of the main axis, which reaches a height of from 3 3/4 to 5 feet in the first year of growth with rather weak development of lateral branches; laterals from near the base of the main axis are wanting and there is feeble development of secondary laterals from such laterals as develop. The main axis is very leafy with leaves of robust growth and of gradual transition to rosette leaves. When mature the plants of this race appear as shown in PLATE 10 (field label 49). Throughout their growth they are decidedly in contrast to the other races already described.

TABLE 56

Statistical constants for two generations (F_3 and F_4) comprising three series of a tall-growing race (race 6), with the values for the F_2 parent

Pedigree	[*o*]	[*t*]	[*ot*]	[*t*²]	*a*	*b*	*t*
F_2. $(E_{22} \times A)$–*10*–							
no. 8	17.1	40*	− 6.56	344.28	17.7	−0.019	67
F_3. $(E_{22} \times A)$–*10–8*–							
no. 4	16.8	38	− 9.40	535.58	17.4	−0.017	76
" 13	17.3	39	− 5.46	561.36	17.7	−0.011	78
" 15	16.4	44	−23.31	758.37	17.8	−0.032	91
" 14	16.6	35	−18.56	491.63	17.9	−0.038	75
" 12	16.3	34	−25.00	518.30	18.0	−0.049	78
" 8	17.1	18	− 7.06	129.31	18.1	−0.053	37
" 3	17.4	31	−13.78	518.83	18.1	−0.027	74
" 6	17.1	21	− 7.12	124.47	18.3	−0.057	52
" 7	17.5	28	−13.67	365.16	18.5	−0.037	72
" 11	17.8	25	− 9.66	226.33	18.9	−0.043	50
" 1	18.2	39	−17.17	619.32	19.3	−0.028	83
" 5	18.5	28	−11.72	320.26	19.5	−0.036	60
F_4. $(E_{22} \times A)$–*10–8–15*–							
no. 11	15.8	30	−16.47	317.63	17.4	−0.052	62
" 4	17.0	27	− 6.70	301.75	17.6	−0.022	61
" 1	17.0	34	−11.75	440.32	17.9	−0.027	59
" 16	17.1	34	−10.54	391.55	18.0	−0.026	61
" 5	17.6	21	− 4.31	199.53	18.1	−0.022	48
" 2	18.1	16	− 9.28	989.33	18.2	−0.009	32
" 17	17.1	21	−12.81	215.50	18.3	−0.059	51
" 14	17.0	28	−14.70	297.15	18.4	−0.049	56
" 8	17.1	24	−15.67	238.72	18.7	−0.066	49
" 6	17.4	29	−16.02	333.09	18.8	−0.047	61
" 15	17.0	24	−18.45	217.24	19.0	−0.085	47
" 9	17.1	33	−24.90	416.33	19.1	−0.060	67
" 12	17.1	24	−16.15	177.72	19.3	−0.091	49
" 7	17.7	33	−24.10	414.04	19.6	−0.059	52
F_4. $(E_{22} \times A)$–*10–8–14*–							
no. 9	15.7	29	− 2.35	310.05	15.9	−0.008	58
" 1	15.7	31	− 4.38	372.48	16.1	−0.012	63
" 18	15.7	34	−12.66	394.87	16.8	−0.032	68
" 5	16.2	29	− 8.95	256.57	17.2	−0.034	57
" 6	15.4	36	−23.36	482.00	17.2	−0.049	73
" 8	16.5	30	− 8.69	322.41	17.3	−0.027	58
" 16	16.9	31	− 4.24	433.37	17.3	−0.010	70
" 2	17.1	27	− 5.24	278.50	17.6	−0.020	54
" 7	15.6	33	−24.39	399.46	17.6	−0.062	66
" 10	16.0	32	−22.83	397.21	17.8	−0.057	67
" 3	16.9	33	−10.53	382.29	17.8	−0.026	65
" 12	15.9	32	−25.17	381.58	18.0	−0.065	64
" 11	16.4	27	−25.97	391.91	18.2	−0.067	63
" 15	17.4	29	−10.39	310.05	18.4	−0.033	58
" 4	17.3	29	−13.95	307.71	18.6	−0.046	60
" 13	17.7	30	−26.93	349.57	19.9	−0.073	61

For the F_3 series of twelve plants (TABLE 56) values of *a* ranged from 17.4 to 19.5 and averaged 18.3 with a standard deviation of

±0.62. The further performance of this race was observed in two series of F_4, the progeny of two plants, with values of a which were somewhat lower than the average of the series. In regard to the actual range for values of a and averages, one series was decidedly higher, more uniform and less variable; its progeny digressed toward the higher average of the generation to which the parent belonged. For the other series (*−10–8–14−*), the average a was somewhat lower than the value of the immediate parent, and the range was extended to lower values than were seen in the parent series. All plants of the F_3 and F_4 of this race gave minus values for rate of change.

The two radically different races, semi-dwarf bush (race 5) and the tall-growing race (Race 6), descended from the same F_1 parent $(E_{22} \times A)$ *no. 10.*

The six races noted above all descended from three sister F_1 plants which were quite alike in general vegetative characters. The three main lines of descent split up into six rather widely differing races. In regard to values of a, it may be noted (TABLE 48) that races that segregated from the same line were of the same general performance. Values for races 1 and 2 were relatively high, those for races 3 and 4 were relatively low and those of 5 and 6 were more intermediate.

The differences in values for the lines and the noticeable uniformity within races, especially in the F_4, is proof that somewhat slight differences in number per head are hereditary. Although self-sterility of many plants prevented a rigid testing of the effects of selection, there is decided evidence, as noted above, that selection for high or low values within a race is in some degree effective.

A further point appears to be clear. The very marked vegetative differences may affect very strongly the total number of heads produced, but such vegetative differences are only slightly concerned with changes in the performance as measured by such values as o and a.

DISCUSSION AND CONCLUSION

The aim of the earlier investigators who made statistical studies of number of flowers per head was to obtain exact descriptions of species as such. By determining the number that is characteristic of various species, the degree of specific differentiation in respect to the character of flower number would appear. The results of the various statistical studies (of Ludwig especially) of flower number, although chiefly directed to ray-flowers, have been considered as indicative of specific differentiation, as noted in the review of literature. That the number of rays is not closely or rigidly stable is very evident, however. A rather wide range of variability is nearly always in evidence, and this has led investigators to judge a species by some such value as the average or modal number. When thus judged, it seems clear that species differ and that a species may tend to maintain a particular maximum. The studies with chicory, viewed from this standpoint, indicate that the total number of flowers per head may range in this species from 5 to 34 and that the number per head most frequently produced is somewhere from 17 to 19.

The view held by Ludwig maintains that the numbers for ray-flowers characteristic for species as such conform to such a series as that of Fibonacci, hence there is proof of discontinuous variation or mutation in the evolution of species. However, the data are not fully in accord with this view. It appears that there are some maxima that fall on certain primary numbers of the Fibonacci series and such cases do suggest that fundamental rhythmic processes of development may have occurred giving specific series of numbers for such organs as rays in flower heads. That all flower-number differences seen among and within species thus arose is not indicated, for there are evidently numerous cases of maxima that do not fall on either primary or well-recognized secondary numbers of such series. It will readily be recognized that the indiscriminate statistical study in populations of such a variable character as number of flowers per head centers the attention on general or average performance and fails to recognize the effects of individual and partial variability of a character. Furthermore, a study of individual and partial variabilities furnishes valuable clues as to whether the origin or evolution of different flower numbers per head is of continuous or discontinuous nature.

When the data for an individual plant of chicory are massed there is most often a rather pronounced mode or maximum. A certain number of flowers per head on a plant occurs with greatest frequency. The modal number, however, is not the same for the various individuals of a mixed population or even of a race: for some individuals it falls on as low a number as 14; for others it falls as high as 22. In relatively few cases do the maxima fall on one of the primary numbers of the Fibonacci series and the grand maximum certainly does not thus fall.

A consideration of variation within the individual (partial variability) shows that the number of flowers per head in chicory may range on a single plant from 7 to 31. The primary numbers 8, 13, and 21 of the Fibonacci series are thus all represented on a single plant and the range extends almost to the next in order, 34. Furthermore, as a rule, all numbers between the extremes are represented on an individual. The variations within the individual are certainly continuous rather than discontinuous, at least to the extent that there is no rhythmic discontinuity with jumps to one after another of a series of maxima.

The questions of chance variation, differentiation, and symmetry deserve special mention. In chicory, it is clear that the differences in number per head are not purely chance variations that are due to undiscoverable factors. As fully noted in the literature review above, nearly all the statistical studies, both in methods of collection and in treatment of data, have considered the variations in flower number to be purely chance; but the results obtained in chicory suggest that there may be present sources of variation that are due to differentiation in the sense used by Pearson. The data here reported show that position is a factor influencing flower number. As terminals bloom before their immediate laterals, differences according to position appear in the course of the succession of bloom, giving intraseasonal partial variability. In this sense the more lateral and later-blooming heads are differentiated from the more terminal and earlier-blooming heads of the same plant.

However, the distinction between chance variation and discoverable differences according to position (differentiation) in such similar organs as flower heads in chicory is by no means clear. Partial, chance, or fluctuating variations are of such intergrading ranges that differentiation according to position would not be discovered by such indiscriminate and chance methods of study as have usually been employed. Considering the first terminals and the last laterals which bloom on a plant, there is, as a rule, a very marked difference. There is also a difference between terminals of various ranks. But for certain terminals the number of flowers per head is identical with that of certain laterals; one class grades into the other. A strict interpretation of differentiation, however, would perhaps lead one to the view that even the variation seen in any one day among closely homologous terminals or laterals produced on a plant is significant of still finer grades of differentiation.

Such a view would evidently recognize a symmetry of development giving primary, secondary, and tertiary branches. If such be the case, it is clear that the transition from one to the other is more continuous than discontinuous; at least the gradations are slight. Although differentiation is in evidence, and is readily discoverable, it is not obviously discontinuous.

In chicory the repeated branching and deliquescent habit of growth with terminal and lateral branches of various ranks and series give opportunity for a full expression and development of marked differentiation of the sort discussed above. If the differentiation which does occur in chicory in development of number of flowers in such homologous organs as flower heads is any measure of differentiation between individuals, races, or species as such, it is indicative of continuity rather than discontinuity.

In judging an individual as a whole for flower number per head, the collection of data at the beginning of the blooming season will give a different estimate from what would be obtained at the close of the blooming season. As a rule, higher values prevail in the first part of the blooming period. The variability observed will be less the shorter the period of time covered. There will be less variability with the limitation of data to terminals only, to laterals only, or to terminals or laterals opening during one day.

The collection of data from a number of individuals to be compared in any sort of statistical study may therefore involve several decided elements of error. The collection of the same amount of data is not alone adequate, for the two sets may represent different relative periods of bloom. Even if data were taken for a period of bloom, as for the first ten days, they would most often represent different proportions of the entire period of bloom. Data from the last period of bloom only would give an unreal and apparent similarity between plants, as all plants are more nearly alike in the lower numbers per head produced during the late season. Data for the first period of bloom would emphasize the differences in the higher numbers per head. Indiscriminate collection of data from individual plants therefore involves so many sources of misrepresentation as to be of little use in formulating any conclusions. It is quite possible that much the same condition exists in respect to the hereditary studies of such characters as the size of flowers (as Goodspeed and Clausen, '15, have suggested) or as the size and weight of fruit produced or of any other character which is subject to such degrees of partial variability.

The data for chicory indicate that there is much individual variability in such a character as number of flowers per head. Such differences as total number of flower heads and length of blooming period are quite closely correlated with vegetative vigor and variations of this sort are seen even in closely inbred and very uniform races. Much more fundamental differences exist especially between plants of different races or between races as such. The modal number and the computed value of the first day of bloom may be quite different. The rate of change as determined by values of *b* may be decidedly different, even to the point of exhibiting no seasonal decrease or even of revealing an actual increase in number as the season advances. While such cases are not numerous they are sufficiently frequent (for this the data are fully convincing) to indicate that the usual processes of noticeable differentiation according to position which result in seasonal decrease may not be in evidence or may even be reversed in their operation so that the differences between terminals and laterals as to number per head do not appear and hence both terminals and laterals show much the same range of variation. These individual differences arise among plants of the same age that have been grown under as similar conditions as is possible under greenhouse and garden culture.

The individual variations observed are to be considered as fluctuating and continuous. They indicate that the character of flower number is constantly varying, giving differences upon which selection may operate in the isolation of races.

The performance of races with marked differences in vegetative habit of growth gives some clue to the extent to which the character of flower number per head can be modified in correlation with different habits of growth. The various races range in habit from extremely robust and much branched races with annual production of large numbers of flower heads to small dwarf races which produce only a few flower heads in a season. The total number of heads produced and the length of the blooming period are greatly modified in such cases. The character of number per head, however, remains more constant. In the most vigorous types we have found, as a rule, high values for the computed number of first day of bloom. Also, it is in the most vigorous races that partial variability is greatest in degree, for here lowest numbers per head (as low as 5) are found.

The possibility of isolating races which will exhibit characteristic differences (although often slight) in flower number is well demonstrated, though rigid selection is here difficult because of the limitations imposed by self-incompatible plants. The continued selection in self-fertilized lines of descent for extreme and unusual characteristics appearing within a race is impossible in chicory because of self-sterility and the limits of the effects of selection cannot be so rigorously tested as is possible in a species fully self-compatible.

Hereditary variations of slight differences and of continuous gradation appear in every group of organisms with which extended studies of heredity have been made. The two current interpretations of such phenomena are (1) those of the strict adherents of the genotype theory who see only recombinations of Mendelian units and (2) those of the selectionists who see evidence of continuous alterations in constitution upon which selection may operate.

The experiments of Castle and Phillips ('14) show that selection for variations in color patterns of rats led to a gradual increase or decrease in the amount of pigmentation, ultimately giving quite diverse patterns. These results have been continuously and consistently interpreted by Castle to indicate that "genetic factors are themselves variable" and that such factors may be altered gradually but permanently by repeated selection and "that one must reject the conception of modifying factors and conclude that the character has a high degree of genetic stability yet is subject to continuous genetic fluctuation" (Castle and Phillips, '14; Castle, '16a, '16b, '17, and other papers).

Much the same sort of variability has been demonstrated, however, in progenies propagated asexually by Stout ('15) in *Coleus* and Jennings ('16) in *Difflugia*. Here the fundamental hereditary characters are shown to be subject to slight and hereditary alterations.

Jennings ('17) points out that modifying factors, postulated by the opponents of the doctrine of fluctuating change in hereditary constitution to account for a series of graded variations in sexually reproduced and cross-bred organisms, are themselves alterations.

Johannsen ('03) claims that in respect to such a variable character as weight and size of seeds an ordinary population of beans consists of a number of genotypes (races) which can be discovered by growing and comparing the progeny of single seeds. Each progeny constituting what he calls a pure line was considered as breeding true except for occasional mutations. Johannsen thus sought to apply the doctrines of discontinuous mutation then so recently announced by de Vries and to establish the genotype theory to account for the isolation of races differing in hereditary constitution (genotype). The variations appearing within a line of progeny were considered as purely due to environment (phenotypic).

There are at least two methods of attacking the problem as to the inheritance of variations, such as those of weight of seeds within a line of progeny:

1. By comparing the seed weights of progeny of small and large beans irrespective of immediate parentage within the line and irrespective of a consideration of individual or partial variability.

2. By comparing the progeny of different plants which vary in the average of their total product, with the estimate of individual variabilities which takes into account the partial variabilities that are present.

Either method is good if properly carried out. The first method, however, is less satisfactory in that it does not consider partial variability. The extremes of partial variations may include, as they do in chicory, the very lowest and the highest values of range. It is, however, the first-named method that Johannsen chose to use. Furthermore, the far-reaching conclusions published by Johannsen ('03) were based on the results of *one crop for which the offspring of small and large seeds produced by the same plant were grown and compared as to size and weight of seeds which they produced as classes*. As far as any line was concerned, the selection constituted a test for the heredity of *partial variations only*, as Belling ('12) has already noted. The negative results obtained indicate that the weight of individual seeds produced in the same pod or in different pods on the same plant, as was the case in each of the 19 lines, is largely due to differences in nutrition (phenotypic), resulting from position in the pod or to relative position of the pod. It seems clear that adequate tests for the heredity of variations in the character of weight of seeds in beans should be based on the performance of plants as wholes rather than on the weight of the individual seeds.

Johannsen ('13) reports progenies beyond his first generation from a known parent plant (his 1902 crop) from only two of the original nineteen plants. These two were plants of near the average rather than the extreme performance. In these two lines of progenies, however, the performance of individual plants was not considered and as selection was on the basis of the weight of individual seeds, those selected for high and low weights may have repeatedly had the same parentage.

Even with this method, however, there is evidence that hereditary variations of fluctuating nature arose within a line. In line I, the weight range of beans produced by the parent plant (1901) extended from 550 to 750 milligrams. The next crop of seeds (produced by at least several sister plants) ranged from 350 to 900. For several years later the *average weights* of the heavier and the lighter seeds planted were beyond the limits of the entire range of the seeds of the original parent plant. The actual ranges of the successive crops, which might show multimodal irregularity, are not given; only the average weights of all above or below the mean are presented. Here, however, the data show that the range of variability in offspring of a single plant may far exceed that of an original parent. While this increased variability is interpreted by Johannsen as within the range of variability of the genotype such results are not at all inconsistent with the view that actual changes in hereditary constitution are in evidence which when subjected to such careful selection as that employed by Castle and Phillips may result in the isolation of further genotypes within the "pure line."

The necessity of considering the performance of individuals as units in judging a progeny, or a line of progenies, and of representing on this basis the individual variations rather than the partial variations occurring within the individual, when such fluctuating characters as weight of bean seeds and number of flowers per head in composites are involved, is well shown in the studies of chicory reported above. The greatest difference between individuals and between races as such (in respect to flower number) is seen in the production of higher numbers per head rather than of lower numbers. The tendency of the variabilities is to extend the range of flowers per head to higher numbers keeping the range in lower numbers much the same. There is not a decided shifting of the entire range to higher and lower values for the plant or the race as a whole.

This characteristic variability among races, to extend or to limit the range in high numbers rather than to shift the entire range, indicates that racial differentiation is here quite different from that which appears to have prevailed in the races which de Vries ('01) isolated in *Chrysanthemum segetum*. However, de Vries confined his attention chiefly to terminal flowers and practiced a rigid selection for extremes only. In isolating the race with 21 rays per terminal head, various intermediates ranging as low as 13 for a maximum were discarded. At any rate, the isolation of two extreme races by de Vries is no proof that other and intermediate races could not also be isolated quite as they have been in chicory.

The differences between varieties or races of chicory are, considered as a whole, quite continuous. The average number of flowers per head for the first date of bloom (*a*) (computed from the seasonal record of the various members) for the different races isolated in F_3 and F_4 ranges from 20.4 to 16.7. These averages, however, are from distributions that are overlapping (TABLE 48). If the races having highest and lowest values of *a* be massed in population, the curve will be bimodal, the irregularity of which depends largely on the relative numbers. If the race with intermediate values be also massed, then the curve becomes monomodal.

It is clear that in chicory flower number per head is a character that is subject to wide and continuous variability that is (1) partial (existing among the parts of a single individual and here involving also elements of differentiation according to position), (2) individual (characteristics of plants as wholes based on their entire record), and (3) racial (fluctuating about a mode that can be somewhat closely maintained by selection). The differentiation between races as such, however, is no more marked than the differentiation involving position that occurs among the various parts of the individual. Most especially is the character of number of flowers per head subject to modification during ontogenetic development and epigenetic processes of growth. *Flower number per head is very different, therefore, in nature from the general character of the inflorescence as a whole and from the character of flowers as individuals.* All flowers are quite alike, all are in heads, but the number of similar flowers that are thus grouped is variable.

The operation of heredity in such a character as flower number is seen in the isolation of races which may be maintained by such selection as was possible in chicory. Within each race, however, there are further variations, continuous in gradation and of the same nature as those appearing in a more mixed population, which are unmistakable evidences of the instability of characters and hereditary units.

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EXPLANATION OF PLATES 10–13

PLATE 10

Field view of chicory crop of 1916. Field label 49 designates a series of the tall-growing race [race 6, series $(E_{22} \times A)$–*10–8–15*–]. Plants of the semi-dwarf bushy race (race 5) are shown at the right [series $(E_{22} \times A)$–*10–13–5*–,] in front [series $(E_{22} \times A)$–*10–13–13*–], and at left [series $(E_{22} \times A)$–*10–13–12*–] of field label 49. Field label 53 marks a series $(A \times E_{22})$–*9–5–6*–, of the brittle-stemmed race (race 4).

PLATE 11

View in field of chicory, crop of 1916. To left, field label 53 marks a series of the brittle-stemmed race shown also in plate 10. Next to the right are plants of the semi-dwarf race [race 1, series $(A \times E_{22})$–*4–3–11*–]. In front of label 63 are plants of the dwarf race [race 2, series $(A \times E_{22})$–*4–6–3*–]. Field label 63 designates plants of series $(A \times E_{22})$–*9–5–6*– and label 57 marks series $(A \times E_{22})$–*9–4–10*–, both of which constitute distinct races thus far unnamed.

PLATE 12

Branches of chicory from near middle part of plants. A is from the wild white-flowered plant *A* used as a parent of various families; B is from plant E_3 of the variety Barbe de Capucin, and C is from an F_1 hybrid of $E_3 \times A$.

Heads that are solitary and on terminal or elongated stems are indicated by 1. Sessile flower heads lateral to more terminal heads are indicated by 2. Clusters of sessile heads are shown at 3.

As shown, especially in A, the terminal head blooms before a head that is immediately lateral to it. In the flower clusters the first head to bloom is the main terminal.

The three branches illustrate some of the variations that occur in regard to the number of solitary and grouped heads.

PLATE 13

Segments of a single large branch from each of four different plants showing the grouping of heads, the relative development of successive laterals on a branch, and the variation which is seen in different plants (individual variability) in the character of the clusters of flower heads.

A is from a plant of the variety red-leaved Treviso. (*R. ser. 11, no. 14*). At 8 is a terminal segment with a solitary head at apex and at first node. Segments 7 to 4 inclusive show a terminal and a single lateral at each node with various stages of elongation of the stem bearing the terminal. Segments 1, 2, and 3 show further development; the succession of bloom indicated by letters.

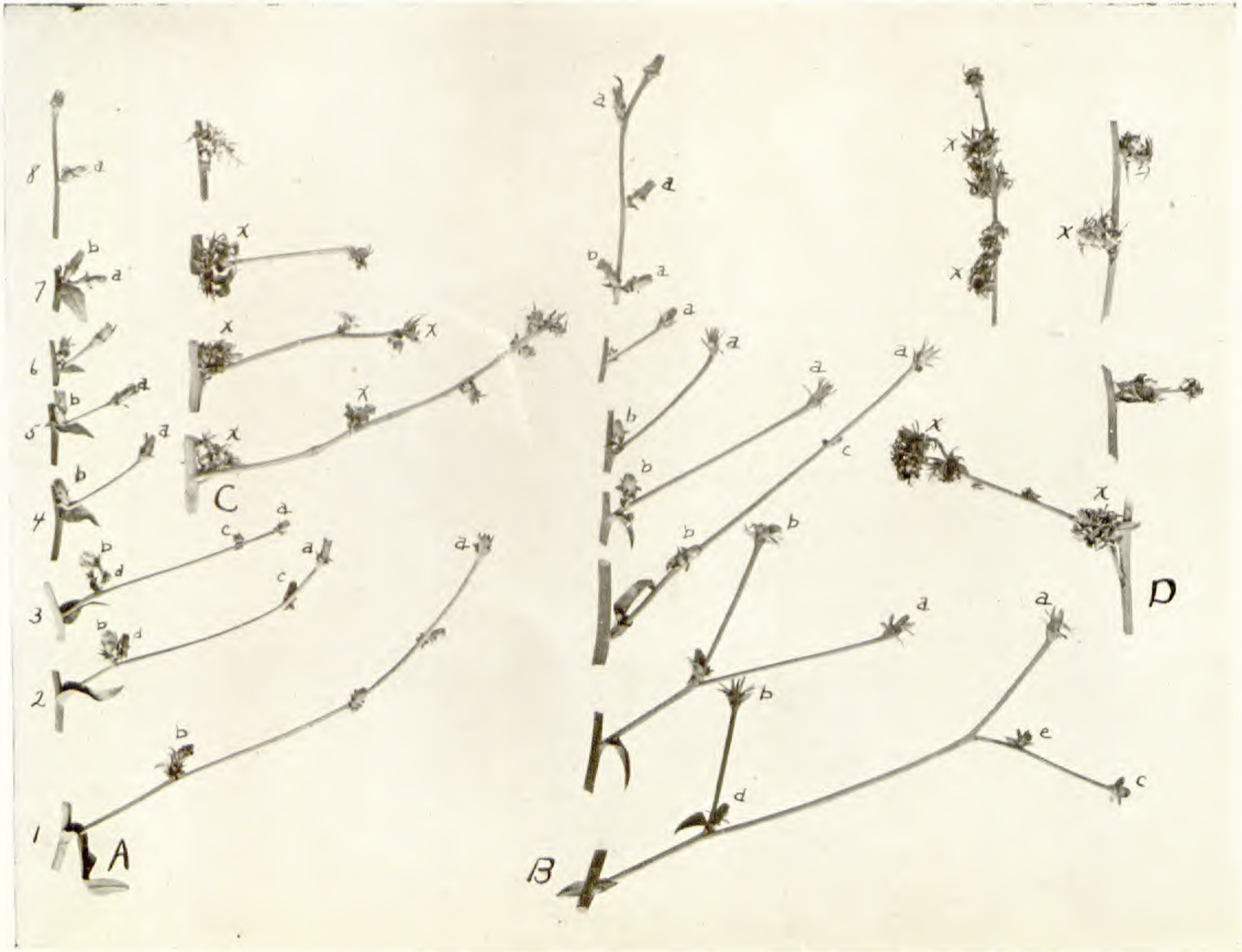
B is from a plant of the F_1 generation of the cross between a plant of red-leaved Treviso and the wild white-flowered plant *A* (plant *RA, ser. 2, no. 5*). Shows rather extreme development of ultimate branches giving few sessile flower heads, a characteristic quite marked in plants of red-leaved Treviso and in wild plants.

C and D are from two plants of the brittle-stemmed race (race 4) showing reduction of the ultimate branches with production of clusters of sessile flower heads. In such clusters are terminals and laterals of different ranks.

STOUT AND BOAS: CICHORIUM INTYBUS. VIEW IN FIELD, 1916, SHOWING VARIOUS RACES

STOUT AND BOAS: CICHORIUM INTYBUS. VIEW IN FIELD, 1916, SHOWING VARIOUS RACES

STOUT AND BOAS: CICHORIUM INTYBUS. BRANCHES SHOWING VARIOUS ARRANGEMENTS OF FLOWER HEADS



STOUT AND BOAS: CICHORIUM INTYBUS. Flowering branches

THE TRIMORPHISM AND INSECT VISITORS OF PONTEDERIA

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(WITH PLATES 14 AND 15)

The family Pontederiaceae is notable as containing the only known heterostyled species among monocotyledonous plants (with one possible exception*) and is further remarkable among heterostyled plants as furnishing the only recorded examples of distinctly zygomorphic or irregular flowers in such plants.

Fritz Müller,† writing in 1869 from Santa Catharina in southern Brazil, described a *Pontederia* which had for several years been introduced as an ornamental plant in the colony of Blumenau, and which increased with incredible rapidity by asexual propagation; the species he thought to be *P. crassipes*, and from the fact that the flowers showed the same relative positions of long and short stamens and style found in the mid-length-style form of the well-known *Lythrum Salicaria*, he was convinced that he was dealing with a trimorphic species of which only the mid-styled form had been introduced. He found another species growing wild on the banks of the Itajahý-mirim, which presented long- and short-styled flowers, but no mid-styled form could be found there. From the finely toothed petal segments shown in Müller's figures of this second species (*loc. cit. f. 1–3*) it almost immediately occurred to me that it was the plant which I have regularly seen labelled *Piaropus azureus* (Sw.) Raf., growing with the more famous water-hyacinth at the New York Botanical Garden, and later I discovered that it is so identified by Müller himself (as

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* It is stated by Kerner (Pflanzenleben 2: 369. 1891; Eng. Ed. 2: 374) that flowers of *Colchicum autumnale* present three style lengths, but his brief description does not indicate any corresponding difference in stamen lengths such as always accompanies truly trimorphic species.

† Müller, F. Ueber den Trimorphismus der Pontederien. Jen. Zeitsch. Naturwiss. 6: 74–78. 1871.

Eichhornia azurea) in a paper published eleven years after his first report.* In this paper the first-mentioned species is positively identified as *Eichhornia crassipes* [=*Piaropus crassipes* (Mart.) Britton], the water-hyacinth, which has so conspicuously exhibited the same habit of rapid vegetative propagation in the St. John River in Florida, and Müller reports that during 1881–2 he found long-styled plants of this species, hitherto known only in the mid-styled form. These long-styled plants he thought could have appeared in the Blumenau region only as the illegitimate offspring of mid-styled parents.

In the English edition of Hermann Müller's classic handbook on flower pollination† published in the same year as this last paper, *Pontederia* (*Eichornia*) *crassipes* [sic] is described as existing in the colony of Blumenau "in long-, mid-, and short-styled individuals." This statement is doubtless an error on the part of the translator and editor, for it would seem improbable that Hermann Müller should have had such information from his brother Fritz at that time. This error appears to be transferred to the other species in the Engler-Prantl treatment of the Pontederiaceae, for there‡ it is stated that *Eichhornia azurea* has trimorphic flowers, while of *E. crassipes* only a long- and a mid-styled form is known. Our view of the misapplied character of these last two reports finds confirmation in the carefully edited handbook on flower pollination by Knuth§, where no later original work on these species is indicated than Fritz Müller's second paper, and where any such almost certainly would have been mentioned if it had been published. Further examination of the water-hyacinths would be of considerable interest.

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* Müller, F. Einige Eigenthümlichkeiten der *Eichhornia crassipes*. Kosmos **13**: 297–300. 1883.

† Müller, H. The fertilisation of flowers through insects, 561. 1883. (Translated by D'Arcy W. Thompson.)

‡ Schönland, S. Pontederiaceae. Engler & Prantl, Nat. Pflanzenfam. **2**^{4}: 73. 1888.

§ Knuth, Paul. Handbuch der Blütenbiologie. **3**^{2}: 113, 114. 1904. It is perhaps worth while to call attention to the fact that the English translation of this work, issued in three large volumes, covers only the first two volumes of the original; the third German volume (posthumous) devoted to extra-European plants, and therefore most useful for American students, contains several references to American literature which nearly escaped the attention of the present writer, owing to the failure of the translator and editor to mention the abridged character of the English edition.

Darwin* in his book on heterostyled plants, published in July, 1877, reports a "third species of *Pontederia*" recently discovered by Fritz Müller, which had all three flower forms growing together in the interior of Brazil. I was at first inclined to suppose that this was another species of *Piaropus*, for it seems strange that so acute an observer as Darwin should have been so bound by the conservative English conception of these plants current at that time, as to fail to distinguish between the large-flowered, many-seeded forms then beginning to be segregated on the continent as *Eichhornia*,† and the small-flowered, one-seeded *Pontederia;* but that this third species was a true *Pontederia* is attested by Fritz Müller himself six years later (*op. cit.* 297) when he also states that it was collected near Curitibanos in the highlands. This species may have been *Pontederia rotundifolia* L., or one of the imperfectly known allied forms; details of Darwin's description indicate that it could not have been our *P. cordata* L., or *P. montevideensis* Hort. (see note, p. 466) although the former is reported to grow as far south as Argentina, and the name of the latter suggests for it a South American origin.

The first mention of heterostylism in our native pickerel-weed, *Pontederia cordata*, is found in a brief note by Mr. William H. Leggett‡ a prominent early member of the Torrey Club, and probably first communicated in a meeting of the Club. In November, 1875, he reported having noted during a previous season an appearance of di- or trimorphism in this plant, but his somewhat inaccurate description, based upon examination of dried flowers, led Darwin to express doubt whether the species is really heterostyled. In August, 1877, the month following the publica-

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* Darwin, Charles. The different forms of flowers on plants of the same species, 183–187. 1887.

† The very natural genus *Piaropus* (thick feet) was established by Rafinesque in 1837 on *Pontederia azurea* and *P. crassipes* (Flora Telluriana **2**: 81, 82); nevertheless these two species continued to be treated under the generic name *Pontederia* in most of the literature for about four decades thereafter. If the principle of priority is ever to be maintained, there can be no justification for such provincialism in science as that practised by the Brussels Congress in ordering Rafinesque's well-founded name for a small strictly American genus published in Philadelphia to be rejected in favor of the Teutonic *Eichhornia* Kunth (Enum. Plant. **4**: 129. 1843) published six years later, even though Kunth's name was latterly attaining some degree of currency among continental writers.

‡ Leggett, W. H. *Pontederia cordata.* Bull. Torrey Club **6**: 62, 63. 1875.

tion of Darwin's book, Mr. Leggett reported* that he found on examination of growing plants that *Pontederia cordata* "is as truly trimorphic as *Lythrum Salicaria*, or even more so." His brief account appears to have received little notice in this country, for only one of our manuals mentions the trimorphism, and to answer some of the questions raised by Mr. Leggett as to the insect visitors, the relative fertility of the three forms, and the function of the peculiar glands which beset the flowers, was the purpose of the investigations now to be reported.

Early in July, 1916, while searching for another plant seen during a previous season at Arcola, a trolley station about midway between Hackensack and Paterson in Bergen County, New Jersey, I was attracted by the opportunity to secure a good photograph in natural surroundings of our pickerel-weed—a plant which does not seem to grow extensively in the immediate vicinity of New York. Here at Arcola it was abundant in two long ditches in a pasture, and presently the attempt to obtain a photographic record of its numerous insect visitors became a fascinating pursuit. I made many visits to the station during the remainder of July, August, and September, always laden with cameras and butterfly-net and killing-bottle. Flowering spikes were generally brought back from the field for laboratory study, and though all the flowers opening on any one morning begin to fade often by mid-afternoon if the day is sunny, later if it is cloudy or humid, nevertheless when brought to the greenhouse, the spikes would be furnished with freshly opened flowers for several successive mornings. The flowering proceeds in general from below upwards, but as not more than one of the three or four flowers of a single spikelet or sessile cluster of buds is open at one time, the main portion of the spike may be well clothed with new flowers for some days. In this way the biological advantages of conspicuousness of the whole inflorescence and economy in condensation of the axis and spacing of the open flowers are maintained at the maximum degree of efficiency.

As Mr. Leggett discovered, the species consists of three kinds of plants, each kind bearing a flower of somewhat different form. At one time I thought the different plants might be recognized by

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* *Loc. cit.* 6: 170, 171. 1877.

differing shades of color in the flowers, as described by Fritz Müller for *Eichhornia azurea*, in which he found the short-styled flowers regularly of a deeper blue, and the long-styled flowers of a paler, more violet tint; but on another day all of the spikes were indistinguishable in this respect. By a little observation of the position of the anthers, however, one may easily recognize the three forms without having recourse to dissection of the flowers (PLATE 14).

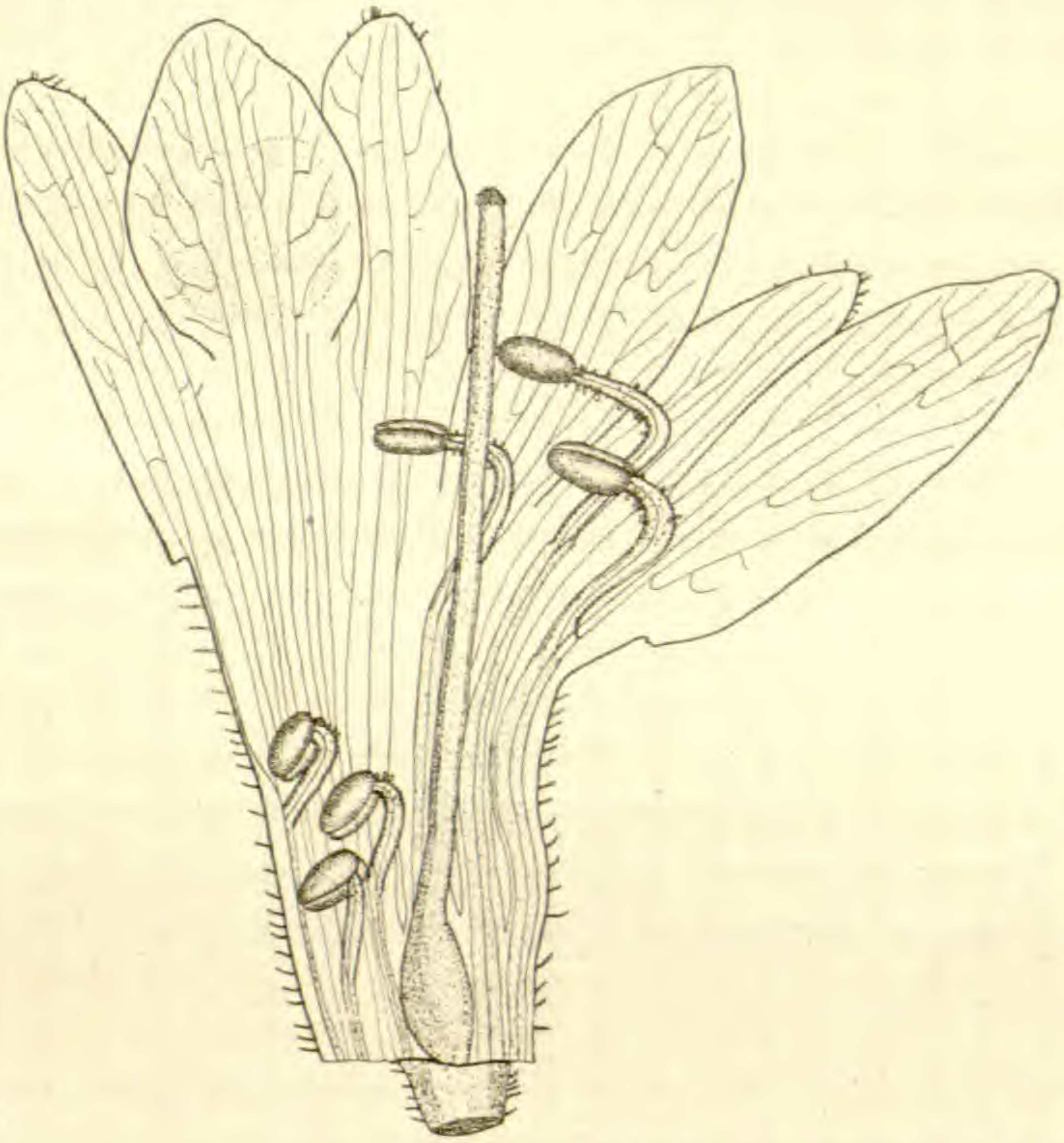

FIG. 1. *Pontederia cordata* L.; flower of the long-styled form with the perianth tube cut lengthwise and laid open to show the typical position and relative height of all the stamens (× 5).

In all of the three flower forms the three narrower sepal-segments and the three ovate petal-segments are united into a tube about seven or eight millimeters in length, which, however, often has four narrow slits in its lower part between the segments on the anterior or lower side of the flower, so that it would seem to be less efficient as a nectar receptacle than many tubular flowers. These clefts are so inconspicuous that they do not appear in any of my sketches made from fresh flowers, but are evident in material preserved in formalin (FIG. 1) and in pressed specimens, from which one might suspect that they are formed in part at least by shrinkage. Similar clefts are found in *Piaropus.* The three spreading segments of the lower lip form a convenient landing platform for smaller insects. The three segments of the upper lip are rather erect and form a sort of standard with a conspicuous mark on the posterior petal-segment which has been regarded as a nectar-guide for insects, a large double blotch of bright yellow—rarely two separate spots as often described, at least in plants from several regions examined by the writer. The yellow pigment is located in a layer of cells immediately underneath the inner epidermis, and appears to be diffused in the cytoplasm of these cells; they extend outward in irregular scallops on the periphery of the spot, producing a border slightly more greenish in tint, hardly perceptible to the eye, but noticeable in photographs made with a color-screen too light to bring out the correct value of the main part of the spot (PLATE 14). Except in the region of this yellow blotch, the cells of both the inner and the outer epidermis show a rather violet-blue pigment dissolved in the cell-sap, and in addition each cell contains a conspicuous globule of a clear indigo-blue color, consisting either of solid amorphous anthocyanin or possibly of a tannin or protein substance impregnated with pigment.*

In the lower part of the perianth tube the blue color is lacking and some chlorophyl may be present, but examination with a lens reveals pink spots due to single large subepidermal cells containing a pigment dissolved in the cell-sap, of a slightly purplish-red tint and having an acid reaction. Similar hypodermal cells are found throughout the pistils, where they also contain red pigment at least in the short-styled form (FIG. 8). In the middle and upper regions of the perianth, where the epidermal cells are blue, much larger scattered hypodermal cells occur in abundance (FIG. 2) but when dissected out, these are found to be colorless; to assume, however, that anthocyanin is absent from

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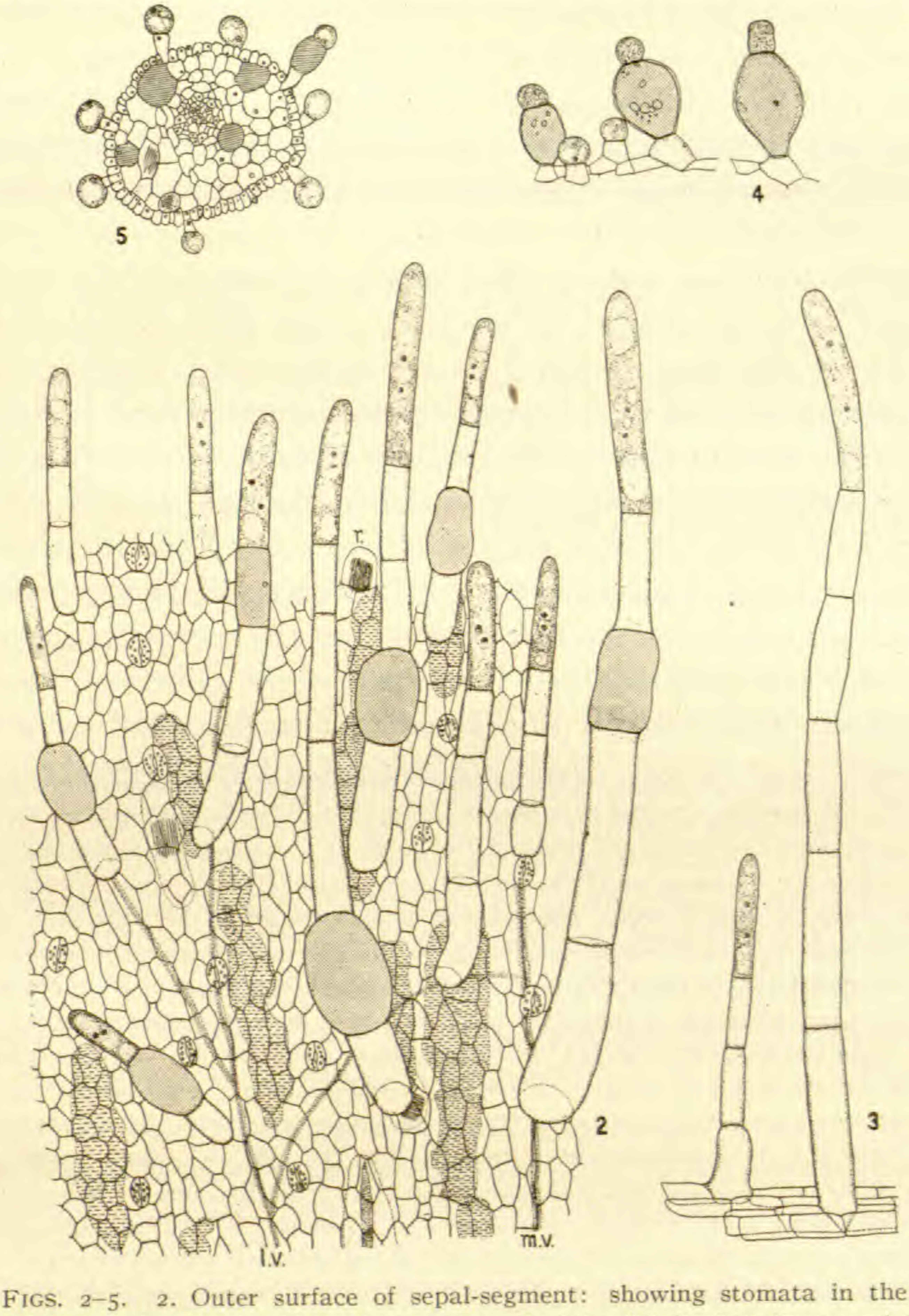
* When the cells are treated with hydrochloric acid and osmic acid (employed as a tannin test) this deep blue globule turns to a wine-red color, and the dissolved anthocyanin may be precipitated in small globules of the same color. If copper acetate is used, the globule turns to an emerald green color and the precipitated anthocyanin shows the same tint. Such a combination of dissolved and solid anthocyanin was first described and figured in *Gilia* by Hildebrand in 1863, but has been little mentioned since until 1906, when Gertz in his important work *Studier öfver Anthocyan* reported the wide occurrence of such a condition; summarized in Miss Wheldale's book, The Anthocyanin Pigments of Plants 32–35. 1916.

them is unsafe, since Willstätter finds that in *Centaurea* and some other plants purple, red, or blue anthocyanin may readily change to a colorless isomer. These large cells were first noticed in ma-



FIGS. 2–5. 2. Outer surface of sepal-segment: showing stomata in the epidermal layer; large subepidermal idioblasts shaded with broken lines, and three raphide-sacs (*r.*) in the same layer; the mid-vein (*m.v.*) and a lateral vein (*l.v.*) lying underneath; on the surface, hairs of two forms (× 105). 3. Typical simple glandular hairs on the lower part of the perianth tube (× 105). 4. Hairs near tip of filament of mid-length stamen (× 113). 5. Cross section of filament from a bud 3 mm. long; showing a raphide-sac, and several of the elongated hypodermal idioblasts shaded (× 113).

terial preserved in formalin and in alcohol, by both of which their contents are turned to a reddish-amber color.*

Both the red-pigmented and colorless cells respond to several of the usual tests for tannins, and their contents may be similar to those of certain idioblasts which occur in the diaphragms of the stem, both in *Pontederia* and in *Piaropus*. Olive† thought the substance in these idioblasts was probably a fatty oil, but Rothert‡ reports that although these cells are filled with a strongly refractive, ordinarily red-brown substance, yet in autumn the substance may be colorless, and can then be determined by the customary reactions to be tannin. I have also found these stem idioblasts to be colorless in plants of *Piaropus azureus* and *Pontederia montevideensis* growing in the conservatory in mid-winter, when they likewise seem to give the tannin reactions. Nevertheless, these microchemical tests for tannins, unsatisfactory at best, are so complicated by possible mixtures of other substances that we feel they are merely suggestive here. The large cells of the perianth, described above for the first time so far as I can find, appear to resemble the subepidermal idioblasts in the petals of *Fumaria officinalis* discovered by Zopf§ and at first described by him as

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* In writing this report on the pigment-containing cells, and on other peculiar cells which have been tested with reagents, I have depended somewhat, for checking up observations on preserved material, on plants of *Pontederia montevideensis* Hort. growing in the conservatory of the New York Botanical Garden, which furnished the only available fresh flowers; comparative studies, however, indicate that all the structures in question are so similar in the two species as to leave no room for doubt of the applicability of these statements to *P. cordata*. The plants of *P. montevideensis* came from Cambridge, England, in 1901, and have been propagated vegetatively; the origin of the species appears to be unknown, and its botanical characters are undescribed, according to Bailey. In vegetative habit it closely resembles the narrow-leaved forms often distinguished as *P. cordata lancifolia* (Muhl.) Morong, but I am confident it is distinct from that. Rothert (Bot. Zeit. **58**: 96. 1900) probably had the same plant from the Berlin Botanical Garden, under the name *Eichhornia montevidensis*, which he says shows such complete agreement in leaf structure with *P. cordata* as to lead him to suspect that it is no *Eichhornia*, but a *Pontederia*. The spelling *montevideensis* has been adopted from Index Kewensis Suppl. **4**: 188. 1913, and is in harmony with the French practise in forming the name of the inhabitants of Montevideo, though *montevidensis* is said to be more in accord with Latin usage.

† Olive, E. W. Contributions to the histology of the Pontederiaceae. Bot. Gaz. **19**: 183. *pl. 17. f. 5, 6.* 1894.

‡ Rothert, W. Die Krystallzellen der Pontederiaceen. Bot. Zeit. **58**: 78. 1900.

§ Zopf, W. Ueber die Gerbstoff- und Anthocyanbehälter der Fumariaceen. Bibl. Bot. 1^2: 20. 1886. For more literature on this subject see Solereder's Syst. Anat. of Dicotyledons (Eng. Ed.) **1**: 57. 1908.

containing a blood-red tannin; later it transpired that Zopf had confounded true anthocyanin receptacles with "sac-cells" occurring throughout the vegetative structures of Fumariaceae, which he finally considered to be alkaloid-receptacles, though Heinricher, who gave the name "sac-cells," states that their contents are a mixture of substances, including a fatty oil.

The rôle of these peculiar perianth cells in *Pontederia* (and in *Piaropus*) can only be surmised at present, whatever the nature of their contents. In fixed and stained sections they often behave much like mucilaginous or gummy substances, and if of such a nature might possibly function in protecting the perianth from danger of desiccation until after anthesis, when the upper part promptly rolls up and soon dries, though the tube persists as an increasingly fleshy envelope around the ovary until the seed is mature. Even in the open flower, some of these large hypodermal cells are often found with their thin protoplasmic layer collapsed, and the contents apparently discharged; half of such a cell is shown at the bottom of FIG. 2. It is interesting to note that the stamen filaments in both *Pontederia* and *Piaropus*, which have blue anthocyanin in their epidermal cells, are well supplied with these long, mostly subepidermal idioblasts; but in the case of *Pontederia montevideensis*, though they are conspicuous in filaments of flowers grown out of doors in September, they appear to be entirely absent in filaments of mid-winter, conservatory-grown flowers, while still persisting in the perianth of the latter. In April, after two or three weeks of sunshine, the flowers of the same conservatory plant have the cells sparingly developed in the filaments and showing a pink anthocyanin color. That a temporary suppression of such structures should occur in consequence of lack of need for them is rather incredible; the suggestion, rather, presents itself, that the contents of these idioblasts, as perhaps also the numerous raphide-sacs which are early found in a similar position in perianth, pistils, filaments, and most abundantly in the anthers, are after all only in the nature of by-products of metabolism.

The outer surface of the perianth is clothed with spreading glandular hairs (FIG. 2); their elongated terminal cell, rich in protoplasmic contents and sometimes binucleate, is not infrequently smeared with a secretion which behaves under reagents much like certain globules visible inside the cell; the other cells show very scant cytoplasmic contents. Many of the hairs, however, particularly toward the tip of the perianth segments, have one cell notably distinguished from the others, often by its swollen ellipsoid form, but always by its strongly refractive, colorless contents contained in the vacuole which practically fills the cell. To anticipate a possible suspicion that these hairs are abnormal, it may be remarked that they also occur on the perianth of *Pontederia montevideensis* and of *Piaropus azureus*. On the upper part of the stamen filaments are hairs of apparently similar character, though consisting of only three cells, a basal cell set in the epidermis, a terminal globular secreting cell, and between them a barrel-shaped cell with colorless refractive contents (FIGS. 1, 4). This cell is perhaps slightly more resistant to reagents than the swollen cell of the perianth hairs, but in both the presence of tannins is indicated, though probably not associated with exactly the same other substances that may be found in the hypodermal idioblasts. These peculiar stamen hairs are developed early (FIG. 5) and in buds only three millimeters long the barrel-shaped cell occasions difficulty in sectioning, much more than the hypodermal cells. More thickly sprinkled over the upper part of the filaments, and also the upper part of the long- and mid-length styles (FIGS. 9, 10) are simpler hairs, consisting only of the globular secreting cell and a basal cell. LeMaout and Decaisne* figure the short-styled pistil as fringed on one side with numerous spreading hairs, but I have always found it almost entirely devoid of such structures.

Growing plants of the form known as *Pontederia cordata lancifolia*, collected 23 March 1918 near Tampa, Florida, by Professor and Mrs. R. A. Harper, arrived in New York in good condition a week later, with only the flowers withered. These somewhat dried flowers, when soaked out in water, showed a blue color in the idioblasts of the hairs on both filaments and perianth; the subepidermal idioblasts in the upper part of the perianth also showed a fine deep prussian blue color, though all the anthocyanin had disappeared from the epidermal cells, except for the solid

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* LeMaout et Decaisne. Traité général de Botanique. 607. 1868.

globule. This same change of the colorless idioblasts to blue has also been observed in fading flowers of *P. montevideensis* treated in a similar fashion, while the pink idioblasts remain unchanged in appearance.

It would be a matter of much interest to be able to determine the function of these three sorts of hairs. Kerner and Stahl* would doubtless regard the perianth hairs as a protection against undesirable creeping insect visitors and snails. If this were their function, here it might have been more easily secured if the hairs had been developed on the large spathe-like bract just below the flowers. Goebeler† regards the glandular and tannin-bearing hairs abundantly present on young fern shoots as serving in a much higher degree as a protection against desiccation, by diminishing transpiration, and by absorbing and storing water or conducting it back to young tissues. *Pontederia* shows a strong tendency to dry up on the slightest provocation, and the hoary glandular covering so conspicuous all over the young buds and even over the stem down to the point of insertion of the bract, may well furnish a protection against excessive transpiration. Along this line, it is also suggestive, that the hairs on the stamens and styles are chiefly found on the parts exposed when the flower is opened, and that they are almost entirely absent from the short-styled pistil, which is so completely enveloped by the perianth tube as to need no other protection. The longer stamen hairs do also, in some cases at least, catch the pollen from the anthers and hold it in the most advantageous position in relation to insect visitors, but it can hardly be supposed that so specialized a form was evolved for such a purpose. Knuth‡ found that the flowers of *Sicyos angulata* L. acted upon a photographic plate much more strongly than their inconspicuous greenish-white color would lead one to expect, and suggested that this may be due to the numerous glands covering the flowers which possibly "act as so many mirrors or lenses receiving and reflecting light, so that their glitter strongly

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* Stahl, E. Pflanzen und Schnecken. Jen. Zeitsch. Naturwiss. **22**: 557–684. 1888.

† Goebeler, E. Die Schutzvorrichtungen am Stammscheitel der Farne. Flora **69**: 483–497. 1886. See also Gardiner, E., & Ito, T. On the structure of the mucilage-secreting cells of *Blechnum* and *Osmunda*. Ann. Bot. **1**: 30. 1887.

‡ Knuth, P. Handbook of Flower Pollination. **1**: 87. 1906.

affects gelatine sensitized by silver bromide, and also the optic nerves of insects." If such a theory has any basis in fact, it might be applied to the hairs of the stamens, and possibly also of the styles of *Pontederia.*

There can be no doubt that the numerous insect visitors of the pickerel-weed seek it for the nectar it affords. It was at first supposed that this was secreted by the basal region of the perianth, but on examination of sections I found that the fleshy character of the tube is due chiefly to the presence of numerous air chambers separated by diaphragms much as in the stem structures, and that nothing like nectar-secreting cells can be detected there. In sections of the ovary, however, are found conspicuous epidermal cells lining the three slit-like cavities left by the incomplete fusion of the carpels (FIGS. 6, 8); these and one or two layers of cells beneath them stain deeply because of their rich protoplasmic contents and large nuclei, and there can be no doubt that they secrete nectar which flows freely from the open lower end of the narrow cavities to form an accumulation in the perianth tube. These secreting cells were indicated in the figures of *Pontederia* given by LeMaout and Decaisne* and by Wilson Smith,† but their significance was not discussed. Similar septal nectaries were discovered in 1854 by Brongniart‡ in several genera; their histological development was more exactly studied by Saunders§; and their variety of form and phylogenetic development in many genera of the Liliales, Scitaminales, and Bromeliaceae have been more elaborately set forth by Schniewind-Thies.||

Ovary sections of *Pontederia* show also several groups of cells whose large nuclei and abundant protoplasmic contents present practically the same appearance as those of the septal nectaries; these groups of cells are found imbedded in the tissue of the anterior carpel, and in the solid portion of the two anterior septa lying above the septal nectaries, which do not reach higher than

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* LeMaout et Decaisne. *Loc. cit.*

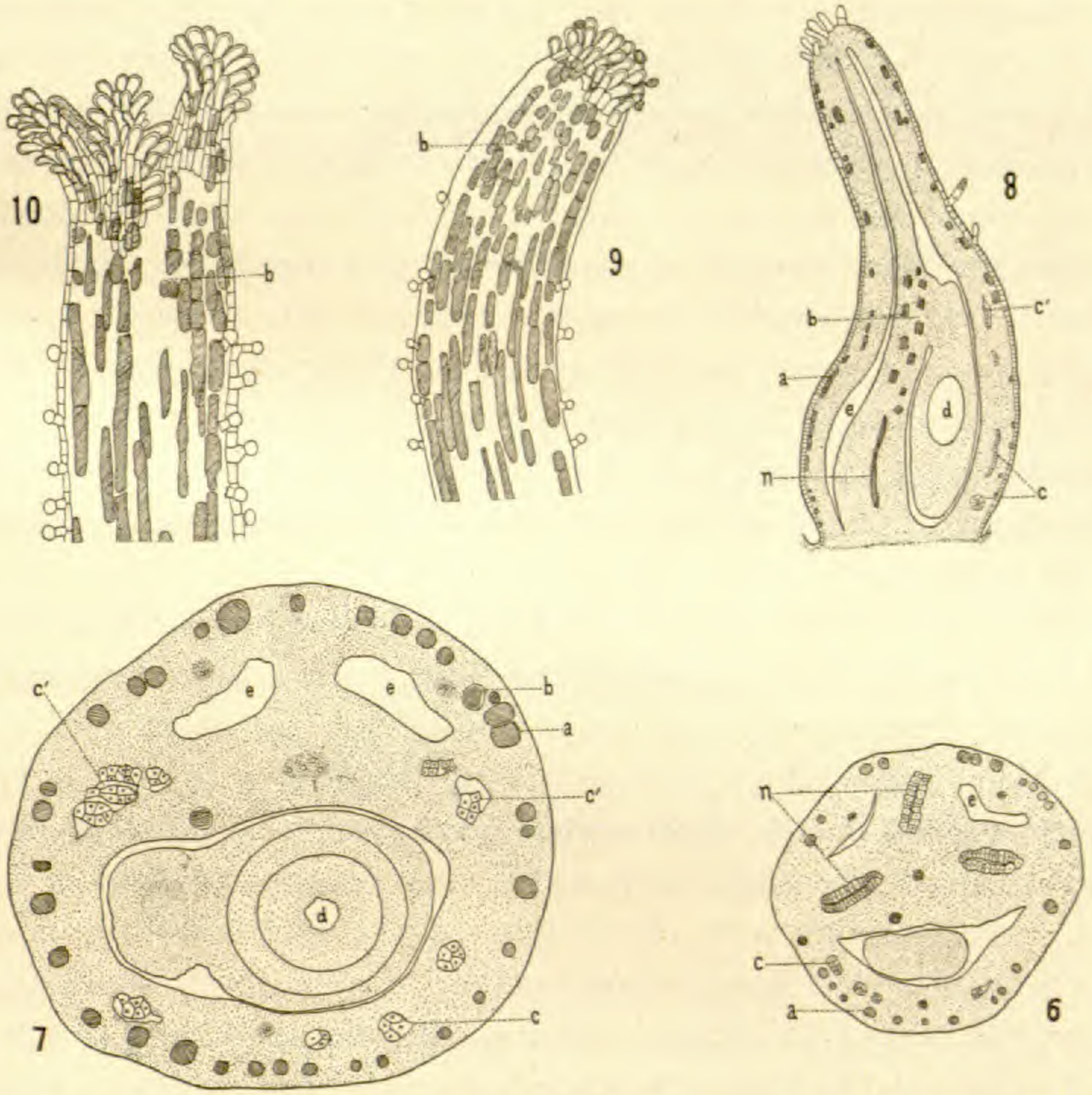
† Smith, R. Wilson. A contribution to the life history of the Pontederiaceae. Bot. Gaz. **25**: 324–337. *pl. 20. f. 54.* 1898.

‡ Brongniart, A. Mémoire sur les glandes nectariféres de l'ovaire dans diverses familles de plantes monocotylédones. Ann. Sci. Nat. Bot. IV. **2**: 5–23. 1854.

§ Saunders, E. R. On the structure and function of the septal glands in *Kniphofia.* Ann. Bot. **5**: 11–25. 1890.

|| Schniewind-Thies, J. Beiträge zur Kentniss der Septalnectarien. 1897.

the middle of the ovary (FIGS. 7, 8). Often even in a young ovary these cells abut on small schizogenous cavities, as at c' in FIG. 7, and in older sections of *Pontederia montevideensis*, where they are more extensively developed, the cavities may form elongated canals lined with secretory cells. The fact that these cells appear to be functional long after these of the septal nectaries cease to show any trace of secretion indicates that they may belong to a quite different category.



FIGS. 6–10. 6. Section through lower half of ovary, short-styled form (× 57). 7. Section through central part of same ovary (× 100). 8. Longitudinal diagram of similar ovary, constructed from threee sections (× 35); from buds 3 mm. long. 9. Curved style-tip of mid-styled flower with small and mid-size pollen grains germinating on the stigma (× 35). 10. Six-parted stigma of long-styled flower, three of its divisions lying behind those shown; epidermal cells indicated only at the top; below the elongated subepidermal idioblasts, shaded (× 37). *a*, anthocyanin idioblasts, shaded, mostly subepidermal; *b*, bundles of raphides; *c*, groups of secretory cells, at c' abutting on small schizogenous cavities; *d*, embryosac; *e*, empty loculi; *n*, septal nectaries.

The stamens are always in two sets; a longer set of three on the anterior side of the flower, consisting of a pair opposite the lateral petal-segments, with a median one slightly longer, opposite the lowest or anterior sepal-segment· the three short stamens of the posterior set· have the shortest one always opposite the upper blotched petal-segment, flanked by a longer one on either side opposite the lateral sepal-segments (FIG. 1); the stamens of this pair show about equal length in the short-styled flower, but in the long- and mid-styled flowers one is longer than the other, so that the three anthers of the shortest sets stand one above the other in the narrow tube in such a position that an insect's proboscis would almost certainly graze all three when seeking the nectar accumulated in the basal portion of the tube. The longer stamens would generally be described as inserted on the perianth tube about at the throat, but they may easily be traced as thickened ridges down to the base of the tube.

The stigma of the long-styled form reaches a height of 12–13.5 mm., averaging (in ten flowers) about 12.5 mm., and corresponding fairly closely with the height of the longest stamen of the mid-styled form, which is 13.5–15 mm., and also with that of the longest stamen in the short-styled form, which is 13–14.5 mm. The stigma of the mid-length-styled form reaches a height of 7–8 mm., corresponding with the longest of the mid-length stamens of the long-styled form, whose anther stands about 9–10 mm. above the base of the ovary, and also with the mid-length stamens of the short-styled form, whose median or shortest another stands 6.5–8 mm. above the base of the ovary. The stigma of the short-styled form is only 2.7–3 mm. above the base of the ovary, and the shortest stamen of the long-styled form has the tip of its anther 3–3.5 mm. above the base of the ovary, while the anther tip of the shortest stamen in the mid-styled form measures 2.6–3 mm. above the base of the ovary. Measurements of all three stamens of the mid-length sets would show a closer correspondence with the mid-length style, but it may be noted that the stamens of the shortest sets are all generally taller than the shortest styles.

The ratio of the average height of the long pistils to that of the mid-length pistils is approximately as 100 to 60; and the average height of the long pistils to that of the short ones is as 100 to 22.

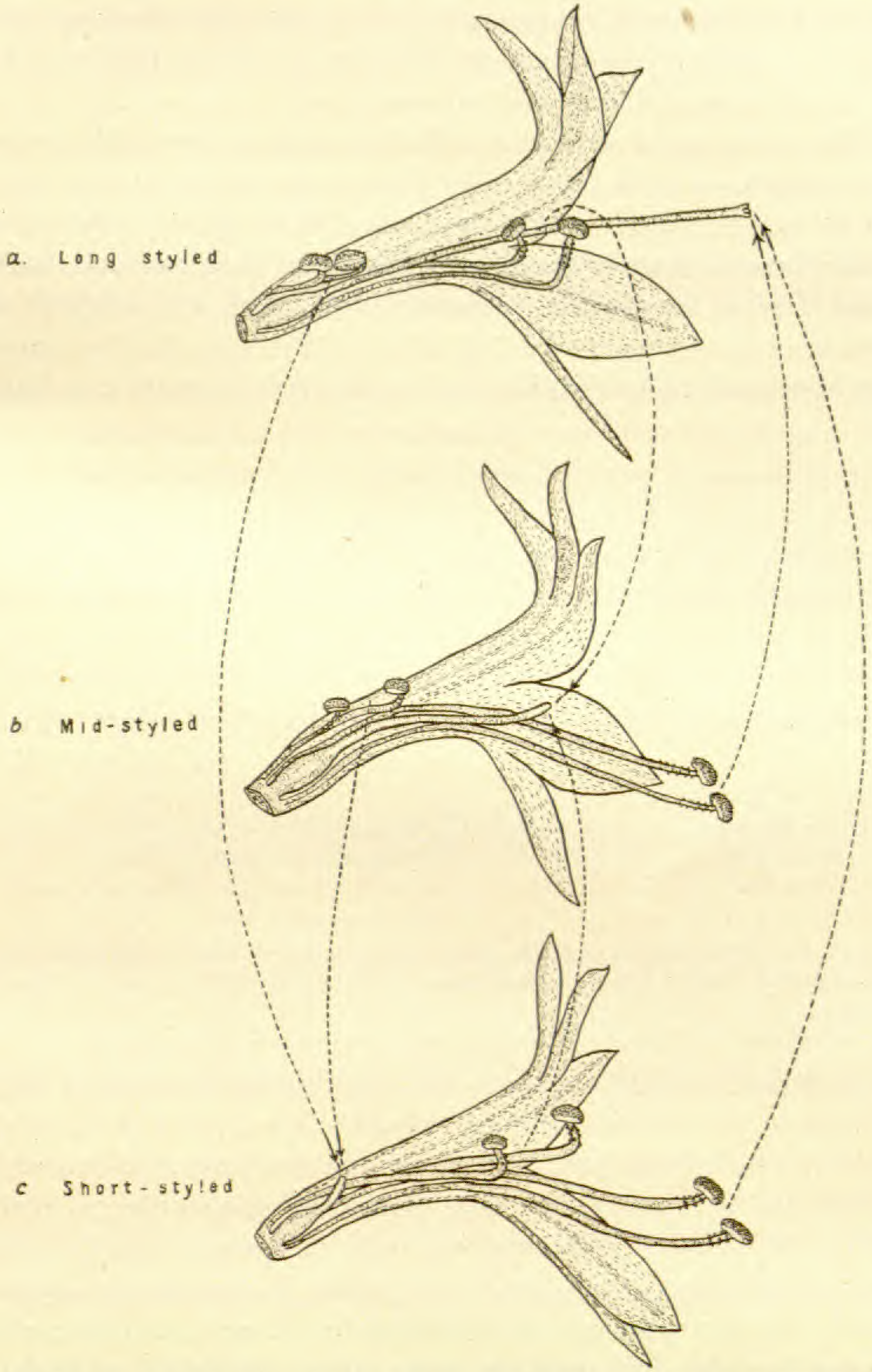


FIG. 11. *Pontederia cordata;* flowers of the three forms in approximately natural position (× 4). The dotted lines with arrows indicate the six legitimate pollinations. From each flower the left lateral petal-segment with its stamen, and half of the left sepal-segment and its stamen have been cut away, in order to show the position of the short stamens with their inverted anthers and the short pistil. Drawn 28 August 1916.

The six legitimate crosses which may take place between the six sets of stamens and the three different pistils are indicated by the dotted lines and arrows in FIGURE 11.

The pollen grains from the different stamens show differences in size similar to those reported by Darwin for the water-hyacinths and for the *Pontederia* found by Fritz Müller in the interior of Brazil; those of the two longest sets of stamens from mid-and short-styled flowers are largest, indicating that they are adapted to pollinating the long-styled pistil; those of the very short stamens from long- and mid-styled flowers appear about a quarter as large (their actual volume averages only one seventh as great) indicating that they would pollinate only the short-styled pistil; while those of the mid-length stamens of the long- and short-styled flowers are intermediate in size, indicating adaptation to pollinating the mid-styled flower (FIG. 12). Unfortunately for convenience of exact comparison, the pollen grains of our species usually are not spherical, as intimated by Darwin for the species studied by him, but they are here rather ellipsoidal or lemon-shaped; in only ten out of three hundred measured have I found isodiametric grains.

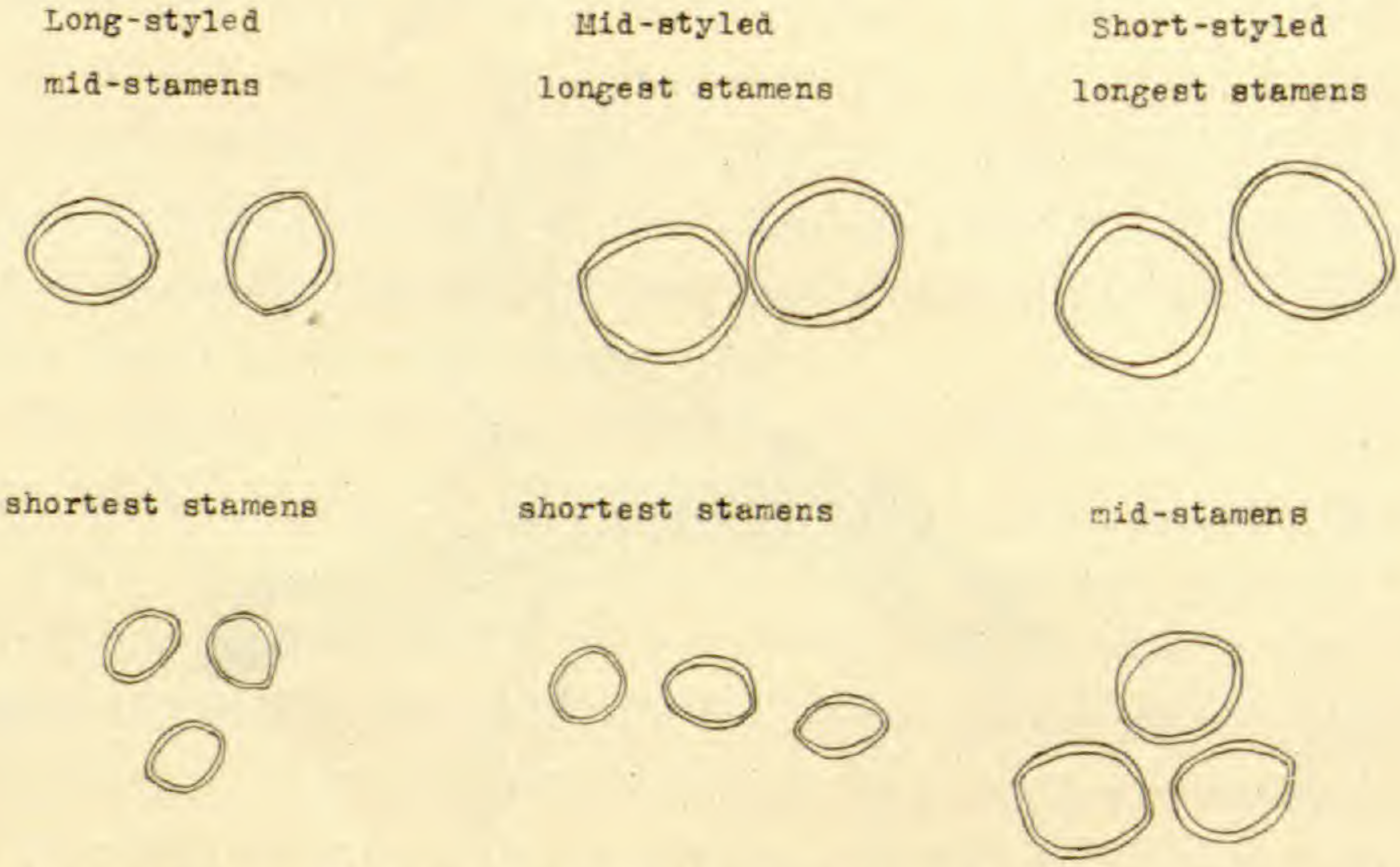


FIG. 12. Pollen grains from the three flower forms, to show comparative size, and similarity of those taken from stamens of similar length in the different forms (× 200).

In order to obtain as definite a record as possible, five flowers of each form were selected, each flower from a different spike, except in the case of the short-styled form, of which only three spikes had been preserved, and from each flower five pollen grains from the longest stamen and five from the shortest were selected at random and measured by means of the eyepiece micrometer. The twenty-five measurements from each of the six stamen types were then averaged. Some weeks later a duplicate set of twenty-five measurements was made in the same manner, and while they averaged uniformly slightly greater than those of the first set, the difference was only such as might be expected because of the personal equation, though in each of the three forms of the second set it was noticeable that one or two of the flowers were especially vigorous, as shown by a considerable increase in size of all grains, both larger and smaller, above the average for similar anthers in other flowers. Nevertheless, when the second set of measurements was combined with the first, the ratios between the different sized grains diverged from those obtained from the first set by only a negligible amount, indicating the substantial reliability of the work. The fifty measurements of each type of pollen give the following result:

Long styled form, from median mid-length stamens	37.44 × 33.79	microns
" " " from shortest stamens	23.94 × 21.69	"
Mid-styled form, from longest stamens	46.33 × 41.61	"
" " " from shortest stamens	23.95 × 20.95	"
Short-styled form, from longest stamens	45.84 × 41.32	"
" " " from median mid-length stamens	36.94 × 33.01	"

It will be seen that the pollen grains from the two sets of longest and shortest stamens correspond most closely, the mean diameters of the shortest sets differing by less than half a micron, but even the divergence between the mean diameters of the two mid-length sets amounted to only seven tenths of a micron. There is a much closer correspondence here than in the smaller number of measurements made by Francis Darwin for his father on the Brazilian plant. It does not appear whether Darwin selected pollen grains from more than one anther of each type, and there is considerable variation in different plants. The extremes found in *Pontederia cordata* may be of interest. The grains from the median (i. e., longest) mid-length stamen of the long-styled flowers showed such averages in different flowers as 35.4 × 34.2, 39.3 × 36, and 36.6 × 33 microns; the similar grains from the median (i. e., shortest) mid-length stamen of the short-styled flower showed such averages as 34.8 × 32.7, and 38.1 × 33.6 microns. The average for a single flower of grains from the longest stamen in the mid-styled form ranged from 42.3 × 37.2 to 49.5 × 42.3 microns; while the small grains from the shortest stamen of a single long-styled flower furnished such averages as 22.8 × 23.1, 24 × 21, and 25.8 × 23.1 microns. The proportions of the grains are by no means constant, and in examining many grains one gains the impression that the two (or really three) diameters balance each other even more than is indicated in these sample averages, that is, that when one diameter increases beyond the average, the other decreases correspondingly so as to keep the volume average more constant than appears. It should be remarked that the above measurements were all based on material preserved for a year in formalin, and that they uniformly average less than a small number of measurements made in August 1916, of grains taken from fresh flowers and mounted in water. These few measurements of fresh grains, considered not enough to be reliable, in general approach more nearly the dimensions of a series made by Halsted* whose report came to my notice only after my own had been completed. As indicated by Halsted, dry pollen from fresh anthers is so contracted as to make its measurement of little significance. It might be expected, however, that though the amount of swelling of the grains would be greater when mounted in water than when fixed in formalin, nevertheless it would be proportional in similar grains, whatever the medium used; and as a matter of fact the ratio between my large- and mid-size grains is almost exactly the same in fresh and preserved material; a greater difference between the size of large and smallest grains mounted in water as compared with similar grains in formalin, I assume to be chargeable to the small number of measurements of fresh grains.

In order to obtain a comparison between our ellipsoid pollen-grains and those reported by Darwin as spherical, the measure-

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* Halsted, B. D. Pickerel weed pollen. Bot. Gaz. 14: 255–57. 1889. In this brief article, no indication of the number of measurements is to be found; with the mere statement that "only three prevailing dimensions" occur, and indications of faulty calculations, it seems worth while to detail my own definite results.

ments of each of the two similar sets of grains given above were combined, and the mean of the three diameters of the average grain of each kind was then taken; this makes the mean diameter for all the large grains 43.3 microns, for all the mid-size grains 34.66 microns, and for all the small grains 22.16 microns. On this basis the ratio of all the large to all the mid-size grains is as 100 to 80, and the ratio of the large to all the small grains is as 100 to 51, which is a slightly greater difference than that reported by Halsted, who pointed out the fact that *Pontederia cordata* shows the greatest range of pollen size yet recorded for any flower. This method of averaging, however, is not accurate, and in any case comparison of volumes would seem to be more significant. Computing the volume of spheroids with diameters represented by the measurements detailed above, or, more simply, calculating the ratios only by use of logarithmic tables, it is found that the volume average of the two sets of large grains is to that of the mid-sized grains as 100 is to 53, and the ratio of the volume of the large to that of the small is approximately as 100 to 14. It will be seen that these ratios present a much better basis for comparison with the ratios of style length than the ratios of the diameters. Darwin's comparison, however, was based on the extremes of size in single sets of pollen grains. In our plant the largest and smallest sets of grains are found in the mid-styled form, where the ratio of mean diameters is as 100 to 50, and the volume ratio about as 100 to 13. In our species, as in Darwin's Brazilian plant, the pollen grains of both sets of stamens in the short-styled flower are slightly smaller than those of the stamens of corresponding length in the other flower forms.

The significance of these differences in pollen size is a point of much interest. Delpino regarded the difference in size as a direct adaptation to the style length, supposing the larger grains could produce a pollen-tube long enough to penetrate the length of the long style, and that the tube of the smallest grains would readily grow only the length of the short style. This view Fritz Müller considered confirmed by his experimental work with *Eichhornia crassipes** where he found that long- and mid-styled pistils

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* Müller found, for example, that flowers on a long-styled spike legitimately fertilized by pollen from the long stamens of mid-styled flowers produced 141.7

pollinated with grains from the smallest anthers were less fruitful than in the case of other illegitimate crosses.

An additional suggestion may be gathered from Halsted's experiments made to determine whether the small pollen grains were fertile, since doubt on this point had been expressed by more than one previous writer. He found all the grains equally capable of germination if sufficient time was given, but that the largest grains germinated much more promptly. In *Pontederia* such promptness of germination of the large grains would be of great importance for the long- and mid-styled plants, inasmuch as the style withers so early that the pollen-tube of a slow-germinating grain might be unable to reach the ovule. I have found that large- and mid-size pollen-grains of *P. montevideensis* both germinate very quickly in weak sugar solutions; the only apparent difference is that the pollen-tube from the mid-size grains has a diameter about three fourths as great as that of the large grains. I had no flowers containing small grains for comparison. But this is a point which can hardly be settled by study of one small group of species.

In *Lythrum* and other heterostyled flowers it has been noted that the stigma of the long-styled form is larger than those of the mid- and short-styled flowers, and it has been considered that the longer stigmatic papillae are adapted to receive the large pollen-grains. In *Pontederia cordata* there is very little difference in the length of the papillae in the different stigmas (FIGS. 8–10) but the stigma of the long-styled flower is frequently, though not uniformly, six-parted, and this spreading stigma may be regarded as directly correlated with its exserted position, for such a stigma would have a distinctly better chance of being dusted with pollen by the insect visitor. In the case of the mid- and short-styled pistils, however, there is no need for such a spreading stigma, since the perianth-tube would almost certainly guide the pollen-smeared proboscis of an insect in such a manner as to brush even a narrow stigma.

Observation of the manner in which the flowers are placed on

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seeds per capsule; other flowers fertilized by pollen from the mid-length stamens of the same spike produced 121.3 seeds; while still other flowers fertilized by pollen from the short stamens of mid-styled flowers produced 113.3 seeds. Kosmos **13**: 298. 1883.

the axis of the spike in a nearly horizontal, though slightly ascending position, indicates that automatic self-pollination is regularly precluded (FIG. 11 and PL. 14). In the long-styled flower the stigma stands out stiffly too far to be reached by pollen from its own anthers, and these are so nearly included in the perianth-tube that pollen from them would be very unlikely even to fall on stigmas lower down on the same spike; in the short-styled form it would be impossible for the pollen to drop down the long, narrow tube to the low stigma. Only in the mid-styled form does it appear that pollen from the long-exserted anthers might possibly fall on the stigma of a lower flower, and here again in all ordinary cases the erect upper lip of the perianth would protect the lower stigma, which furthermore hardly projects from its tube far enough to catch pollen from above.

Among the insect visitors of the pickerel-weed ten species of Lepidoptera, distributed among five families, and showing nearly all possible range in size were collected during several excursions in July and August, 1916, and all of these but two or three were photographed as they sipped nectar from the flowers, several species many times. The list includes the least skipper, *Ancyloxypha numitor* Fabr.; the yellow-spotted skipper, *Polites peckius* Kirby; the silver-spotted skipper, *Epargyreus tityrus* Fabr.; the variegated fritillary, *Euptoieta claudia* Cramer; the clouded sulphur, *Colias philodice* Godart; the white cabbage butterfly, *Pieris rapae* L.; the viceroy, *Basilarchia archippus* Cramer; the tiger swallow-tail, *Papilio turnus* L.; the black swallowtail, *Papilio polyxenes* Fabr.; and the humming-bird moth, *Hemaris thysbe* Fabr. It is strange that the monarch butterfly, *Anosia plexippus* L., which was frequently seen on neighboring plants of Joe-Pye weed, never visited the *Pontederia*, and the so-called mimic, the viceroy, made only one fleeting visit; they evidently prefer the large flat-topped flower clusters of *Eupatorium* and milk-weed, or the nectar found there; or is it possible that blue flowers do not attract them? Another curious case was that of the pearl crescent butterfly, *Phycioides tharos* Kirby, which was the commonest visitor of the vervain, *Verbena hastata* L., growing close to the pickerel-weed ditch, but never came to the *Pontederia*, though the latter possesses much the same blue color and has a similar flower structure. Perhaps a parallel case is that of the honey-bee, which was the most abundant visitor of the vervain, and is generally regarded as catholic in its tastes, but which was not taken on the pickerel-weed. These cases may have a bearing on the view held by some entomologists, that insects have less color sense than has been supposed, but are much more keenly attracted by odors of particular plants, which may not always be perceptible to man.

Of the Hymenoptera, the following species were taken from the middle to the last of August: the bumble-bees, *Bombus fervidus* Fabr., *B. impatiens* Cress., *B. pennsylvanicus* DeGeer; and a smaller Anthophorid bee, *Xenoglossa pruinosa* Say (?) perhaps only gathering pollen. Of Diptera, one specimen of a large "horse-fly," *Tabanus giganteus* DeGeer, was perhaps only a casual caller.* An aggressive large blue-black bee, observed several times, but always eluding the pursuing reflex-camera as well as the net, was probably one of the carpenter-bees of the genus *Xylocopa*. Schneck† has reported that *Xylocopa virginica* regularly slits the lower end of the corolla tube to reach the nectary in *Pontederia* and in other plants. In the present case, however, I feel sure that the bee was sucking nectar from one flower after another in legitimate fashion.

Lovell‡ reports as visitors to *Pontederia* at Waldoboro, Maine, July 21 to August 10, 1898, two species of bumble-bees, two species of small cliff-dwelling bees, one collecting pollen, and four species of Diptera, all feeding on pollen; butterflies, he states, were comparatively rare, and only *Colias*, *Pieris*, and *Argynnis cybele* Fabr. are mentioned. During one warm but cloudy afternoon in August, at the New York Botanical Garden, I saw no butterflies visiting *Pontederia*, but only bumble-bees. Similarly, during August, 1917, abundant colonies of pickerel-weed growing in the open border of Lake Cossayuna in Washington County, New York,

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* For the identification of these insects I am indebted to Dr. Frank E. Lutz, of the American Museum of Natural History, whose Field Book of Insects published in January, 1918, will be a handy guide for the student of floral biology. The Lepidoptera, identified by myself, were all compared with specimens at the American Museum.

† Schneck, J. Further notes on the mutilation of flowers by insects. Bot. Gaz. **16**: 313. 1891.

‡ Lovell, J. H. Three fluvial flowers and their visitors. Asa Gray Bull. **6**: 63–65. 1898.

were watched from a boat, and no butterflies, but numerous bees were seen visiting the plants, though one of the photographs taken there shows clearly a humming-bird moth with extended proboscis poised before a flower. Knuth would doubtless place this plant having a perianth tube of seven or eight millimeters in length among his groups of bee- or humble-bee-flowers, but the record at Arcola shows clearly that such a classification cannot be rigidly adhered to in this case, for there certainly the Lepidoptera surpassed the bees as visitors of this plant both in number of species and individuals. This I think was the case throughout the whole of July and August, though constant pursuit with the camera and net prevented making an exact record of the number of visits of any particular species.

Unquestionably the least skipper, *Ancyloxypha*, was the most frequent visitor, two or three individuals often being present on one spike, and often one of them flitted to several flowers on the same spike in succession; this was always an attractive little butterfly as the golden-brown scales on the lower surface of the folded wings caught and reflected the sun. These smaller butterflies, using the alighting platform furnished by the spreading lower lip of the flower, get the under side of their thorax or abdomen well dusted with pollen from the longest stamens (PLATE 15) and then carrying it to a long-styled flower rub off some of it on the protruding stigma; at the same visit they may dust the head with pollen from the mid-length stamens, or thrusting the proboscis into the tube on the upper side of the flower where there is a wider space between the perianth and the pistil than on the lower side, on withdrawing it after sucking the nectar, they drag it through the row of three inverted anthers of the shortest stamens (FIG. 1) to carry the pollen away to other flowers with appropriate length of style. Larger butterflies, like the silver-spotted skipper, often stand out farther from the flowers so that only the legs and proboscis tip become dusted with pollen, though one photograph of the black swallow-tail shows it grasping the spike with the abdomen tightly pressed against the flowers. The persistent visits of these large butterflies furnish the strongest reason for doubting the rigid applicability of Knuth's classification in the case of this plant. Standing at the south end of a ditch filled, like a garden border, with the bright-flowered plants, I would see a black swallow-tail alight at the north end and flit, sipping restlessly, the whole length of the bed to the point where the camera was focussed on the nearest spike; then he would fly without stopping straight back to the north end, and repeat the performance, until, after three or four exposures in the same place, he was captured. Query, why did he always proceed in the same direction, never reversing? Perhaps for some reason he prefers to sip while flitting toward the sun.

It appears, then, that the pickerel-weed is well supplied with a varied and constant procession of visitors, which must serve it effectively while supplying themselves with food. Although illegitimate pollinations may be frequent, at least some kind of cross-fertilization is undoubtedly the rule after these visits. Self-pollination, however, is probably possible; the little skippers might easily thrust some pollen from protruding anthers down to the stigma of the same flower, or might carry it from one flower to another of the same spike. But the question arises, would such pollination be effective, or are the plants self-sterile? And which of the legitimate crosses are most fruitful? For the purpose of obtaining some light on these points, plants were brought from the field and kept in pots placed in tubs of water in the greenhouse. Numerous crosses and self-pollinations were made, and many of the pistils so treated apparently set seed, but owing to various accidents not so many were brought to maturity. It can only be reported at present that a few mid-styled flowers matured apparently good seed when pollinated from their own long stamens, and also when pollinated from long stamens of other flowers on the same spike; owing to further accidents, no seeds were germinated. More definite results will be looked for from future experimental work.

It is interesting to note that in his second paper* Fritz Müller reported having found himself mistaken in his early assumption that *Eichhornia crassipes* is unfruitful with its own pollen, for although only one plant was introduced in his region, his nephews discovered seeds and young seedlings, and the barrenness had been due merely to the lack of proper insect visitors.

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* Kosmos **13**: 297. 1883.

In the field one is often inclined to think that one of the three forms of the species predominates in a particular locality. This might occur quite as readily as a result of vegetative propagation by rapid growth of the rhizomes as by greater fruitfulness of one form. But the pickerel-weed stem regularly becomes geniculate after flowering, usually just below the insertion of the spathe-like floral bract (the 'knee' is already indicated in PLATE 15) and bending downward, the inflorescence is lowered into the water for maturing the fruits, and they are most apt to fall to the bottom in the near vicinity of the parent plant; in this way also extensive patches of one plant form may be established. Müller reported in 1883 (*op. cit.* 299) that all the Pontederiaceae known to him, including *Heteranthera reniformis* and *H. zosteraefolia*, the two species of *Eichhornia*, and the *Pontederia* from Curitibanos, have this habit of bending the flower-stalk down to the marshy ground or water in which they grow. In 1912 Hauman-Merck* reported, as a peculiarity which he thought had escaped previous observers, this habit of maturing the fruit under water in *Pontederia rotundifolia*, and stated that *P. cordata* growing in abundance in the same places in pools of the banks of the Rio de la Plata matures its fruits out of the water. This statement is rather surprising, since our plants are so fixed in this habit of bending down after flowering that plants kept in the greenhouse with little water develop in a manner precisely similar to those left in the field. *Pontederia montevideensis* shows practically no such tendency when grown here and it would appear possible that Hauman-Merck was really dealing with this species rather than with *P. cordata.*

The final judgment reached at the Arcola station was that all three forms of the plant were about equally numerous there. During the dry August (in the region of New York) of 1917, one visit to the station revealed such a desolate and discouraging group of plants that no attempt was made to do anything further during that season. Perhaps clumps of the plant growing in the borders of the Hackensack River, if they could have been reached, might have proved more rewarding in such a season, for, contrary to the usual statement that this family comprises only fresh water

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* Hauman-Merck, Lucien. Sur un cas de géotropisme hydrocarpique chez *Pontederia rotundifolia* L. Rec. Inst. Bot. Léo Errera **9**: 28–32. 1912.

forms, here plants of *Pontederia* are daily bathed, or even flooded, by tide water.

EXPLANATION OF PLATES 14 AND 15

PLATE 14. *Pontederia cordata:* at the left, a short-styled spike, longest and mid-length stamens protruding from the perianth tube; in the center, mid-styled spike, long stamens only exserted, style-tip barely protruding from tube; at the right, long-styled spike, mid-length stamens only slightly protruding in throat of tube, styles exserted and about as long as the perianth segments. Photographed 10 Aug. 1916, about three fourths natural size.

PLATE 15. Spike of the mid-styled form visited by the least skipper, *Ancyloxypha numitor;* photographed at Arcola, N. J., 15 Aug. 1916.

The drawings for all the text figures were made with the aid of the camera lucida, figures 1–4, 9, 10, and 12 from material preserved in formalin, figure 11 from fresh flowers.

PONTEDERIA CORDATA L.

ANCYLOXYPHA ON PONTEDERIA

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