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REPORT OF THE THIRTY-FIRST ANNUAL MEETING OF THE OHIO ACADEMY OF SCIENCE

E. L. RICE
Secretary

The Thirty-first Annual Meeting of the Ohio Academy of Science was held at Western Reserve University and Case School of Applied Science, Cleveland, Ohio, March 25 and 26, 1921, under the Presidency of Mr. W. H. Alexander. Fifty-nine members were registered as in attendance; forty-seven new members were elected.

In accordance with the practice begun in 1918, but of which discontinuance has since been threatened, a geological excursion was organized by Professor J. E. Hyde, Vice-President for Geology, 1921–22, for the three days, May 28, 29 and 30. The party was under the guidance of Drs. August Foerste and W. H. Shideler. The itinerary (Wilmington, Clarksville, Fort Ancient, Oregonia, Dayton) was planned for the study of the Richmond formations of southwestern Ohio. Like other Academy functions, the excursion was open to non-members as well as members; fifteen geologists were present.

GENERAL PROGRAM.

FRIDAY, MARCH 25.

9:30 A. M.—Business Meeting.
11:00 A. M.—Reading of Papers in General Session.
12:30 P. M.—Luncheon.
2:00 P. M.—Demonstrations.
2:30 P. M.—Reading of Papers in General Session.
3:30 P. M.—Lecture by Dr. Henry H. Goddard, Bureau of Juvenile Research, Columbus, on "Scientific Work at the Bureau of Juvenile Research."
4:30 P. M.—Reading of Papers in General Session.
6:30 P. M.—Dinner.

8:00 P. M.—Address by the President of the Academy, Mr. W. H. Alexander, U. S. Weather Bureau, Columbus, on "Thunder Storms: Especially Those of Ohio."
9:00 P. M.—Adjourned Business Meeting.

SATURDAY, MARCH 26.

9:00 A. M.—Adjourned Business Meeting.
10:00 A. M.—Lecture by Professor Charles A. Kofoid, University of California, Berkeley, California, on "Hookworm and Human Efficiency."
11:00 A. M.—Reading of Papers in Sectional Meetings.
2:00 P. M.—Demonstrations.

SATURDAY, MAY 28—MONDAY, MAY 30.

Excursion by Section for Geology.

MINUTES OF BUSINESS MEETINGS.

The first business session was called to order by President Alexander at 9:30 A. M., on Friday, March 25. Adjourned sessions were held after the presidential address on Friday evening and at 9:00 A. M. on the following day.

The appointment of the following committees for the meeting was announced by the chair:

Committee on Membership—F. C. Waite, E. L. Fullmer, J. E. Hyde.

Committee on Resolutions—C. G. Shatzer, R. C. Osburn, W. H. Bucher.

Committee on Necrology—J. E. Hyde.

The following Auditing Committee was elected by the Academy: L. B. Walton, E. L. Fullmer.

The following Nominating Committee was elected by the ballot of the Academy: F. H. Herrick, E. L. Fullmer, J. E. Carman, F. C. Waite, H. H. Young.

Report of the Secretary.

The following report by the Secretary was received and ordered filed:

March 22, 1921.

To the Ohio Academy of Science:

Much of the work of the Secretary is covered by the Report of the Executive Committee.

The following brief note from Mr. McMillin, in reply to the Secretary's notification of election as patron and fellow, will be of interest to the membership of the Academy and may well have a permanent place in the records of the Academy:

DARLINGTON, MAHWAH, N. J., July 3, 1920.

DEAR MR. RICE:

Your good letter of July 1st was received a few moments ago. I thank the Society for all the honors they have conferred upon me, and greedily accept them all.

Most sincerely yours,

EMERSON MCMILLIN.

Edward L. Rice, Sec'y, Ohio Academy of Science.

There has been some additional correspondecne with the National Research Council concerning the research work of the Academy.

An appeal for the students of the Department of Geography of the Hungarian University of Debreczen was received under date of December 7, and will be presented later in the meeting.

A brief report of the Thirtieth Annual Meeting was prepared for *Science*, and appeared in the issue for August 6th.

In accordance with the instructions of the Academy, the Secretary prepared the Constitution, as amended to date, for reprinting, and it appeared in the Proceedings in connection with the Report of the Annual Meeting.

A number of technical changes in the form of the membership list were necessitated by the designation of fellows and national members (i. e., Academy members who are also members of the American Association for the Advancement of Science). In this revision errors may well have crept in; the secretary will be very grateful for corrections of such mistakes in order that the next list may be made as accurate as possible.

Respectfully submitted,

EDWARD L. RICE, *Secretary.*

Report of the Treasurer for the Year 1920-'21.

The report of the Treasurer was received as follows, and referred to the Auditing Committee, whose report is appended.

Balance in Hayden-Clinton Bank, May 13, 1920, as previously reported	$ 363.90
Deposits	1,357.90
Total	$1,721.80
Less checks	1,206.06
Balance in bank March 17, 1921	$515.74

The distribution of the funds expended is as follows:

To members of the Ohio Academy as refunds from the A. A. A. S.	$ 46.00
To E. L. Rice, Secretarial expenses	12.51
To Independent Print Shop	53.25
To Spahr & Glenn, Printers	8.75
To Hiss Stamp Company	1.40
To James S. Hine for Ohio Journal of Science	500.00
To T. C. Mendenhall, for coupons from bond	4.15
To B. E. Livingston for A. A. A. S.	580.00
	$1,206.06

Cr.

Balance carried forward	$ 363.90	
Cash deposited	1,357.90	
		$1,721.80

Dr.

As itemized expenditures	$1,206.06	
Balance in hand	515.74	
		$1,721.80

The Treasurer feels that the Academy is on a sound financial basis as is indicated in the report. He wishes to take this occasion to thank the members of the Ohio Academy of Science for their cordial support. There have been several cases of delays and misunderstandings in the collection of the joint dues for the American Association for the Advancement of Science and for the Academy. This is greatly to be regretted but from a careful study of the methods of payment, the Treasurer believes that the system will be practically automatic in another year. In order to avoid all trouble and inconvenience, prompt payments should be made in the early autumn when the bills are sent out. This insures prompt notification of the subscription managers of *Science* and of the OHIO JOURNAL OF SCIENCE and uninterrupted delivery of the two journals. Unless the Treasurer has the unanimous co-operation of the members in the matter of promptness, he cannot assure them of immediate attention. He is at all times glad to have reports of errors or delays and willing to do everything he can to adjust matters to the satisfaction and convenience of the members. During the year the present Treasurer has just served he has done practically all the work of billing, dunning, and corresponding unaided. This was done, not so much with the desire to save the slight cost of additional help, as in the hope that he might come to know all the details of the job and especially to straighten out accounts of members in arrears. It is to be hoped that members will take care of their arrearage sooner in the future, but this matter, in the case of those members of the Academy who are also A. A. A. S. members, will quickly adjust itself. In the itemized account of the funds the deposits are somewhat swelled because of arrearage. Because there is no adequate adjustment of this for the Ohio JOURNAL an increase to the JOURNAL was given this year.

While this increase for the JOURNAL comes at a time when it is greatly needed, it should be clear in the minds of the members that the Treasurer does not condone arrearages. A periodical journal can not subsist on alternate fat and lean years. It is desirable that its pabulum be more evenly distributed. Further the Treasurer is definitely preparing to meet the future expansion of the OHIO JOURNAL OF SCIENCE. He believes in it thoroughly and wishes to make it an adequate medium of expression for all the members. The JOURNAL ought to appeal especially to the younger members of the Academy. They need to publish articles in order to become introduced to the older scientific workers. The Treasurer feels that all the money that can be put into the JOURNAL is still not nearly enough to make it the best one of its kind in the country. By making it attractive, the JOURNAL can continue to publish some of the best articles that the members of the Academy can write.

The Treasurer further wishes to call the attention of the members to the fact that Mr. L. H. Tiffany of the Department of Botany of the Ohio State University, has been appointed subscription manager of the JOURNAL. It is his duty to see that all members who have squared accounts with the Treasurer be supplied with all numbers of the JOURNAL to which they are entitled, without further charges. He is at present attending to all cases of non-delivery of the JOURNAL that have come to his attention. All complaints in the matter of the delivery of the JOURNAL sent to Mr. Tiffany can now be cared for. It is thus to be hoped that the members of the Academy will be promptly served.

Respectfully submitted,
A. E. WALLER, *Tresasurer.*

We have examined the above report and found it to be correct.

Respectfully submitted,
L. B. WALTON,
E. L. FULLMER,
Auditing Committee.

Report of the Executive Committee.

The report of the Executive Committee was received as follows and ordered filed:

March 25, 1921.

To the Ohio Academy of Science:

A meeting of the Executive Committee was held in Columbus, December 18, 1920; all members of the Committee were present.

An invitation was received from Western Reserve University and Case School of Applied Science to hold the Annual Meeting for 1921 in Cleveland. The Executive Committee voted unanimously to accept this invitation, and set the date of the meeting for April 1 and 2. The date was later changed by correspondence to March 25 and 26, in order to bring it within the spring recess of Western Reserve University.

The Secretary reported correspondence with Prof. R. C. Friesner, Chairman of the Program Committee of the Indiana Academy of Science, relative to the possibility of a joint field meeting of the two Academies this spring. The joint meeting is rendered difficult by the fact that the Indiana Academy holds a fall meeting for the presentation of papers and a field meeting in the spring, while the Constitution of the Ohio Academy restricts the Annual Meeting to March or April. A joint meeting in the spring must either debar the Ohio Academy from the opportunity for presentation of papers or eliminate the field meeting from the program of the Indiana Academy. The Executive Committee voted its general approval of a joint meeting at some future date, and instructed the Secretary to continue negotiations with the Indiana Academy. The Committee further instructed the Secretary to give notice to the Academy of a proposed amendment to the Constitution removing the present restriction as to the date of the Annual Meeting, unless such amendment shall prove to be contrary to the Charter of the Academy.

The Executive Committee recommended to the Joint Committee on the Election of Fellows that an opportunity be given this year for the nomination of fellows by the present fellows of the Academy on the lines suggested in the pending Constitutional amendment.

Professor Blake was requested to make an investigation of the desirability of an affiliation of the Academy with the Ohio Association of Technical Societies, as suggested in the Annual Meeting of 1919.

The President, Mr. Alexander, was requested to act as Chairman of the Committee on Legislation during the absence of Professor Osborn.

A second meeting was held in Cleveland on the evening of March 24, at which this report was adopted. The President, Treasurer and Secretary were present at this meeting.

Thirty-six new members have been elected during the year, subject to the ratification of the present meeting.

EDWARD L. RICE, *Secretary,*
For the Committee.

Report of the Publication Committee.

The following report of the Publication Committee was received and ordered filed:

The Annual Report of the Thirtieth Meeting (Proc. Ohio Acad. Sci., Vol. VII, Part 5, pp. 117–158) was published on January 17, 1921. It contains the Constitution and By-Laws in addition to the usual matter. Fifty reprints each of the list of members and of the Constitution were also printed. The present arrangement of printing the Secretary's report in the November issue of the OHIO JOURNAL OF SCIENCE followed soon after by the complete annual report seems satisfactory.

Respectfully submitted,
JOHN H. SCHAFFNER, *Chairman.*

Report of Library Committee.

A brief report for the Library Committee was prepared for the meeting by Mr. Reeder; but, owing to a delay in the mail, this report was not received by the secretary until after the close of the meeting. The following report has since been received for publication.

March 23, 1921.

To the Ohio Academy of Science:

The Library Committee begs leave to submit the following report:

(1) The sale of publications during the year has amounted to $1295.

(2) The Proceedings of the 30th annual meeting of the Academy were published in the OHIO JOURNAL OF SCIENCE for November, 1920. Reprints were received late in February and copies were mailed immediately to all persons on the membership roll and to sixty-eight institutions on the exchange list.

(3) The University Library again calls to the attention of the Academy its willingness to lend to any member, through his institutional library, any publication needed in research work. The library is receiving the exchanges from the Ohio Academy and from the OHIO JOURNAL OF SCIENCE, and together with its own purchases and collections in the scientific fields, there is available a remarkable source of literature for advanced study and research. It is hoped that more use will be made of these sources by the scientific men of Ohio.

Very respectfully,
C. W. REEDER.

Report of the Trustees of the Research Fund.

The following report of the Trustees of the Research Fund was received and ordered filed. The financial portion of the report was referred to the Auditing Committee, whose report is appended.

To the Ohio Academy of Science:

The Trustees of the Research Fund submit the following report for the period from May 12, 1920, (the date on which the last report was made), to March 1, 1921.

During this period only two payments from the fund were made: To L. B. Walton, the balance of the grant made to him in 1917, for the study of fresh water organisms; to Miss Elsie Jordan, for a continuation of the work of relabeling the Harper collection of Naiades, under the direction of W. H. Beecher, to whom the grant was made.

Unexpended balances remain to the credit of A. E. Waller, for the study of Ohio vegetation, and to W. H. Bucher, for aid in the making of a geological map of the disturbed area in Adams County, Ohio.

A grant of $150 was made on January 10, 1921, to W. J. Koster, to aid in a survey of the Orthopteran fauna of Ohio.

Correspondence is in progress which may lead to a renewal of the grant made to Paul B. Sears on June 1, 1819, and a further allotment to W. H. Bucher, for the continuation of work originally undertaken by them.

Below is a tabulated statement of receipts and expenditures during the period covered by this report. In this, it will be noted, is included a one hundred dollar Liberty Bond received from the Treasurer of the Academy to be added to the Research Fund and which is held as a more or less permanent investment along with that purchased in 1918. The accrued interest on both of these bonds is added to the active assets of the funds.

At present the amount available for allotment is $569.96, from which it will appear that the demand for the somewhat restricted financial aid to research which this fund furnishes has not been very great during the past year.

Vouchers for all expenditures are submitted herewith, together with the Cashier's certificate of the balance in the bank on March 1, 1921.

RECEIPTS.

Cash in bank May 1, 1920, as per report of that date	$644.68	
Interest on new Liberty Bond, May 15 and July 28, 1920	6.27	
Interest on Liberty Bonds, Feb. 23, 1921	12.76	
Check from Mr. W. Gluttin, Feb. 23, 1921	250.00	
		$913.71

EXPENDITURES.

Elsie Jordan, June 19, 1920	$22.50	
L. B. Walton, January 7, 1921	20.31	
		42.81

ASSETS.

Cash in bank, March 1, 1921	870.90
Total Assets, Liberty Bonds at par	$1,470.90

LIABILITIES (UNDER GRANTS)

A. E. Waller	$ 75.00	
W. H. Bucher	75.94	
W. J. Koster	150.00	
		$300.94

Excess of Available Assets over Liabilities	$569.96

(Signed) T. C. Mendenhall, *Chairman.*
Herbert Osborn.

We have examined the report and found it to be correct.

L. B. Walton,
E. L. Fullmer,
Auditing Committee.

March 25, 1921.

Report of Committee on Legislation.

Professor Herbert Osborn, chairman of the Committee on Legislation, submitted the draft of a proposed bill looking to recognition and financial support of the Academy by the State. The bill, as submitted, is modeled after that establishing the State Archaelogical Society. It was written by Mr. Edge, official "bill drafter" for the Assembly, in consultation with President Alexander, who acted as chairman of the Committee during Professor Osborn's absence from Ohio.

After extended discussion, the report was adopted by the Academy, with minor amendments of the bill, and the Committee was continued with instructions to carry on the campaign. President Alexander was added to the Committee, which, as now constituted, consists of the following: Herbert Osborn, chairman; W. H. Alexander, T. C. Mendenhall, M. M. Metcalf, E. L. Rice, L. B. Walton.

The Committee was instructed to draft such revision of the Constitution of the Academy as may be necessary in case the bill is passed by the Assembly, this action to be interpreted as notice of amendment of the Constitution and as enabling the Academy to take final action at the next annual meeting.

The proposed bill, including the amendments voted by the Academy, follows:

A Bill

Relative to State recognition of the Ohio Academy of Science.

Be it Enacted by the General Assembly of the State of Ohio:

Section 1. The Ohio Academy of Science, a corporation not for profit, incorporated under the laws of Ohio, March 12, 1892, shall be under the control of a board of trustees consisting of fifteen members to serve without salary or per diem. Six of the members of the board shall be appointed by the governor with the advice and consent of the Senate, two to serve for two years, two to serve for four years and two to serve for six years, and until their successors are appointed and qualified, and thereafter two members shall be appointed every two years to serve for a term of six years. The remaining nine members of the board shall be elected by the members of the Academy.

Section 2. On and after the passage of this act, the Ohio Academy of Science shall constitute an official source of advice and information on all scientific questions within its field submitted to it by any state department or officer thereof. The services of the Academy shall be available to the state or any of its officers in any matter within its field in which the consideration of scientific facts or policies may be involved, and the officers of the state may call upon the Academy of Science, through its properly elected officers or committees appointed by its officers, for such consultation and advice as may be of service to them in their duties. The members of such committees shall receive no compensation for their services, except that all traveling, clerical and other necessary expenses shall be paid. No member of the Ohio Academy of Science, while serving on any such committee, shall be eligible for expert service under advice from said committee for which compensation from the state is received.

Section 3. One copy of the "Proceedings of the Academy" shall be distributed to each public library and museum, university, college, normal schools, and first grade high school in the state, and one copy of each number of its official organ, "The Ohio Journal of Science," shall be distributed to each university and college in the state. All exchanges received shall be kept available to the citizens of the state through the library of The Ohio State University, or such other channel as may be determined.

Section 4. The secretary of the Ohio Academy of Science shall be a person well suited by training and experience to perform his duties and may be paid from state funds.

Section 5. The legislature shall make such appropriations from year to year as may be necessary to print the official publications of said Academy and to carry out the other provisions of this act.

Report of Committee on Preservation of Wild Life of State.

In addition to an oral report by the chairman concerning the conservation work already accomplished in Ohio and other states, the Committee presented the following formal recommendations. The recommendations were adopted by the Academy, and the Committee continued under the changed name suggested: Committee on State Parks and Conservation.

The Committee on Preservation of Wild Life of State would recommend:

(1) That the present Committee be continued as a Committee on State Parks and Conservation, to study the various problems involved and to report a matured plan for further action by the Academy.

(2) That all members co-operate in listing suitable tracts for use as state parks, bird reserves, and reservations for the permanent preservation of areas possessing scenic, geologic, or biologic interest.

(3) That the committee proceed to secure co-operation with existing organizations in the preservation of natural conditions in the state forests, game refuges, state controlled tracts, and other areas where such co-operation is possible.

Herbert Osborn,
J. Ernest Carman,
Francis H. Herrick,
C. G. Shatzer,
E. N. Transeau,
Maynard M. Metcalf,
Committee.

Report of Committee on Election of Fellows.

The following report of the Committee on Election of Fellows was accepted and ordered filed:

March 25, 1921.

To the Ohio Academy of Science:

The method of work of the Committee on the Election of Fellows has been as follows:

(1) Through the preliminary announcement of this meeting, the entire membership of the Academy was given the opportunity to make nominations for fellowship. A single nomination was received.

(2) Copies of the membership list were mailed by the Secretary to the eleven members of the joint committee to be checked as nominating ballots. Nine ballots were returned. Five members received three ballots each, four received two ballots, and thirty-four received one ballot.

(3) A meeting was held in Cleveland on the evening of March 24th, at which seven members of the joint committee were present, two were represented by duly authorized proxies, two were absent without representation.

After careful consideration and discussion, seventeen members received the necessary nine votes and were declared elected to fellowship in the Academy. The newly elected fellows will be personally notified, and the list will appear in the Proceedings.

In addition to the constitutional specification of "productive scientific work" as a condition for fellowship, the committee has been guided by the following principles, which it recommends as a general policy for future action:

(1) Members should not be elected to fellowship in the Academy until one year, at least, after election to membership.

(2) Resident members should not be elected to fellowship who are not showing an active interest in the work of the Academy.

This year's committee, like that of last year, took the ground that its action should be conservative. It is probable that good candidates for fellowship have been passed over; it will be the duty of future committees to correct these omissions.

Respectfully submitted,
Edward L. Rice, *Secretary*.,
For the Committee.

The list of members elected to fellowship is as follows:

G. F. Arps
H. H. M. Bowman
E. Lucy Braun
Harold E. Burtt
Dwight M. DeLong
Carl Drake
Wm. Lloyd Evans
Emery R. Hayhurst
Wm. E. Henderson
J. S. Houser
James Ernest Kindred
Sidney Isaac Kornhauser
Florence Mateer
H. C. Oberholser
Paul B. Sears
Victor Sterki
B. W. Wells

Election of Officers.

The following officers and committee members for 1921-'22 were elected by the ballot of the Academy:

President—Professor R. C. Osburn, Ohio State University, Columbus.

Vice-Presidents:

- *Zoology*—Dr. J. E. Kindred, Western Reserve University, Cleveland.
- *Botany*—Professor E. N. Transeau, Ohio State University, Columbus.
- *Geology*—Professor J. E. Hyde, Western Reserve University, Cleveland.
- *Physics*—Professor W. G. Hormell, Ohio Wesleyan University, Delaware.
- *Medical Sciences*—Professor F. C. Waite, Western Reserve University, Cleveland.
- *Psychology*—Professor Rudolph Pintner, Ohio State University, Columbus.

  (Professor Pintner later resigned the Vice-Presidency, owing to removal from the state, and was appointed by the Executive Committee to fill the vacancy.)

Secretary—Professor E. L. Rice, Ohio Wesleyan University, Delaware.

Treasurer—Dr. A E. Waller, Ohio State University, Columbus.

Elective Members of Executive Committee—Mr. W. H. Alexander, U. S. Weather Bureau, Columbus; Professor L. B. Walton, Kenyon College, Gambier.

Member of Publication Committee—Professor L. G. Westgate, Ohio Wesleyan University, Delaware.

Trustee of Research Fund—Dr. T. C. Mendenhall, Ravenna.

Member of Library Committee—Professor W. C. Mills, Ohio State University, Columbus.

Representatives on Editorial Board of Ohio Journal of Science:

- *Zoology*—Professor R. A. Budington, Oberlin College, Oberlin.
- *Botany*—Professor Bruce Fink, Miami University, Oxford.
- *Geology*—Professor G. D. Hubbard, Oberlin College, Oberlin.
- *Physics*—Professor S. J. M. Allen, University of Cincinnati, Cincinnati.
- *Medical Sciences*—Professor F. C. Waite, Western Reserve University, Cleveland.
- *Psychology*—Professor H. A. Aikins, Western Reserve University, Cleveland.

Election of Members.

The Membership Committee reported eleven names for election to membership; thirty-six additional names, previously approved by the Executive Committee and marked with (*) in the following list, were presented for ratification. All were elected, as follows:

*AINSLEE, GEO. G.; Entomology; U. S. Entomological Laboratory, R. D. 9, Knoxville, Tenn.
ALTAFFER, L. B., Chemistry; 7013 Clinton Ave., Cleveland.
*BEAN, RAYMOND JACKSON; Physiology, Embryology; Biological Laboratory, Western Reserve University, Cleveland.
*CHASE, SAMUEL WOOD, Zoology; 1353 E. 9th St., Cleveland.
*CHASSELL, LAURA M., Psychology; Dept. of Psychology, Ohio State University, Columbus.
*CLAYTON, EDWARD E.; Botany; Botany and Zoology Bldg., Ohio State University, Columbus.
*DEVEREAUX, W. C.; Meteorology; Weather Bureau Office, Cincinnati.
*DOBBINS, RAYMOND A.; Botany, Entomology; Dept. of Botany, Ohio State University, Columbus.
*DOCKERAY, F. C.; Psychology; Ohio Wesleyan University, Delaware.
*EMERY, E. H.; Meteorology; 829 Society for Savings Bldg., Cleveland.
*FRIEDLANDER, MAE; Bacteriology, Biology; 343 Carroll St., Akron.
*GODDARD, HENRY H.; Psychology, Sociology; 1638 Granville St., Columbus.
*HARTLEY, EDWIN A.; Entomology; Dept. of Zoology and Entomology, Ohio State University, Columbus.
*HAYHURST, EMERY R.; Medical Sciences; Dept. of Public Health and Sanitation, Ohio State University, Columbus.
HILLS, MYRA E.; Psychology; 2066 E. 100th St., Cleveland.
*JONES, J. W. L.; Psychology; Heidelberg University, Tiffin.
*KNOUFF, RALPH A.; Medical Sciences; Ohio State University, Columbus.
*LUCKEY, BERTHA M.; Psychology; Board of Education, Cleveland.
*MANSON, EDMUND S., JR.; Astronomy, Physics, Mathematics; Ohio State University, Columbus.
*MARSHALL, HELEN; Psychology; Ohio State University, Columbus.
MARTIN, JOHN R.; Physics; Dept. of Physics, Case School of Applied Science, Cleveland.
MATHER, KIRTLEY F.; Geology; Denison University, Granville.
MOORE, DWIGHT M.; Botany; Granville.
*MORSE, PAUL FRANKLIN; Geology; Asst. State Geologist, Jackson, Miss.
*MOXOM, WALTER J.; Meteorology, Physics, Psychology; U. S. Weather Bureau Office, Dayton.
*MURCHISON, CARL; Psychology; The Tallawanda, Oxford.

*Myers, Garry C.; Psychology; Cleveland School of Education, Cleveland.

Niehaus, Wm. E.; Zoology, Geology; Berea.

*Olin, Oscar E.; Psychology, Sociology; University of Akron, Akron.

*Patten, Bradley M.; Zoology, especially Embryology; 1353 E. Ninth St., Cleveland.

*Patton, Leroy; Geology; Muskingum College, New Concord.

*Rea, Paul M.; Natural History Sciences, especially Zoology; The Cleveland Museum of Natural History, Cleveland.

Riley, C. L.; Biology, Geology; 1219 Logan Ave., N. W., Canton.

*Roots, Yale K.; Physics; 412 N. Walnut St., Wooster.

Ross, Herbert W.; Chemistry, Geology; West Technical High School, Cleveland.

*Sayre, Jasper D.; Botany; Dept. of Botany, Ohio State University, Columbus.

*Skaggs, Ernest B.; Psychology; 23 S. Union St., Delaware.

Smith, Ella Thea; Botany, Zoology; P. O. Box 7, Salem.

Smith, Ernest Rice; Geology, Paleontology; 130 Woodland Ave., Oberlin.

*Stone, Julius F., General Science, Grandview, Columbus.

*Strausbaugh, P. D.; Botany, Microchemistry as applied to Plant Physiology; Burbank Road, R. F. D. 10, Wooster.

Tippie, William A.; Physics; 2145 W. 100th St., Cleveland.

*Watson, A. C.; Psychology; Marietta College, Marietta.

*Webb, Robert Fulton; Geology; Dept. of Geology, Ohio State University, Columbus.

*Williams, R. D.; Philosophy, Psychology; Dept. of Philosophy, Ohio State University, Columbus.

*Wurdack, Mary E.; Botany; 29 Twelfth Ave., Columbus.

*Young, Herman H.; Psychology, Educational Research; 235 Chapel Place, Youngstown.

Report of Committee on Necrology.

The following report of the Committee on Necrology was adopted by the Academy and ordered filed.

THOMAS PIWONKA.

September 10, 1854—May 9, 1920.

I first met Thomas Piwonka on the field excursion of the Academy for geology in May, 1919. The failing sight and frailty of age prevented him from participating in full, and he carefully withheld himself from much of the trip that he might not in any way impede the progress of the party. This thought for others was characteristic.

This was less than a year before his death. I saw him but six or eight times in the interval, but these meetings brought us together on the Cleveland shale outcrops of Big Creek which he had often searched for Devonian fish, in his own study and in my laboratory. There are few men that it is possible to know on so short an acquaintance, yet due to a common interest in fossils. I may, I believe, fairly claim to have attained a certain intimacy with him.

It began when he modestly offered to go with me and show me, if I cared to have him, the localities where Dr. Clark, of Berea, had been most successful in his search for fossil fish. "If I cared!" To me, it is an opportunity forever lost that I was able to visit only one locality with this man who had been the intimate companion of Dr. Clark, the indefatigable collector, and Edward Claypole, the elucidator, of the Cleveland shale fish.

With the same modesty, almost with depreciation lest he might seem to intrude himself, he invited me to look over his small collection of fossils from the Cleveland district. When he learned that Western Reserve University possessed almost nothing from the Cleveland shale, he offered me anything of his from that formation "which might be worth having;" the University gratefully received it all. After his death, Mrs. Piwonka, at his request offered the remainder of the collection to the University, "such portion as might be thought worth having." The whole collection is not large, but contains much material from the Cleveland and Sandusky regions, all carefully marked as to locality, all valuable, particularly that from the Cleveland shale which yields material only on long careful search. Some of the material is unique. In earlier years, he had been equally generous with his findings, and the collections of both the United States Geological Survey and of the Dominion Geological Survey of Canada, have been enriched at his hands; in the days when Dr. Clark combed all Cleveland fish-producing localities twice yearly, an occasional choice specimen was obtain by him from Mr. Piwonka, which must since have lodged either in the British Museum or the American Museum of Natural History.

Before his death, he donated to the Department of Geology of Western Reserve University a generous sum of money to defray expenses of members of the department in making extensive field trips or elaborate collections. The donation was unsolicited, and was made with the firm assertion that he did not do it in any effort to perpetuate his name (indeed, he rather insisted that his name be left out of it); that though fortune had not been lavish with him, yet she had not been unkind, perhaps kinder than to most individuals engaged in University work, and he wished to defray a part of the expense that they are frequently put to in the prosecution of their interests. This sum has already been of service, and will be of yet more service, in the recovery of the last fish and amphibian remains that can possibly be obtained from the famous old Linton Coal-Measures locality of eastern Ohio.

Mr. Piwonka was born in New York City of Bohemian stock. He was valedictorian of his class from Central High School, Cleveland. His interest in natural science was first aroused by S. G. Williams, then a teacher in Central High School (who later became Professor of Education in Cornell University, and whose collection forms the bulk of the paleontological collection of Western Reserve University). After graduation, Mr. Piwonka acted as secretary to the superintendent of schools for several years, during which time he found time to prepare himself for admission to the bar in 1876. His life-work was law, but in spare moments he was a naturalist with particular interest in geology, botany and microscopy. His passing removes one more (very few are left) of that generation of men interested in the natural history of their locality, with the collector's keen instinct, to which paleontology is profoundly indebted. With them is passing a phase of our culture.

J. E. Hyde, *Committee.*

Report of Committee on Resolutions.

The following resolutions were presented by the Committee on Resolutions and adopted by the Academy:

(1) The Academy wishes to thank the Local Committee, the officers of Western Reserve University and Case School of Applied Science for their efforts in making the Thirty-first Annual Meeting of the Ohio Academy of Science a success.

(2) The Academy wishes to express its appreciation of the continued interest and financial support given to the research work of this Academy by Mr. Emerson McMillin.

(3) The Academy wishes to express to Professor Charles A. Kofoid, of the University of California, its thanks for the special lecture on "Hookworm and Human Efficiency."

(4) The Academy wishes to thank again Professor E. L. Rice for his efficient services as Secretary of this Academy.

C. G. Shatzer.
Raymond C. Osburn.
Walter H. Bucher.

Amendment of Constitution.

Art. V, Section 3. *Election of Fellows.* Amended to read: Fellows shall be elected by joint action of the Executive Committee and the Vice-Presidents, from nominations endorsed by two fellows of the Academy. Such nominations shall be accompanied by documentary evidence of the candidate's scientific achievements upon which the nomination is based. Approval by three-fourths of this joint committee shall be necessary to election.

Amendment of By-Lwas.

Chap. III, Section 5. *Nomination of Fellows.* New section, to read: A suitable blank for nomination of fellows shall be supplied by the Secretary and shall be mailed to each member of the Academy at least once each year.

CHAP. IV, SECTION 2. *Nominations.* Amended to read: The Academy shall elect by ballot a Nominating Committee, consisting of one representative from each regularly organized Section of the Academy, who shall nominate a candidate for each office, including elective members of the Executive Committee, the Publication Committee, and the Trusteees of the Research Fund. Additional nominations may be made by any member of the Academy.

Proposed Amendment of Constitution.

The following amended form of Art. VI, Section 1, was proposed by the Executive Committee for action at the next annual meeting: *Annual Meeting.* The date and place of the Annual Meeting shall be fixed by Executive Committee, subject to such instructions as shall be determined by the Academy at the preceding annual meeting, and shall be announced by circular at least thirty days before the meeting. The details of the daily sessions of each meeting shall be arranged by the Program Committee and announced in the official program immediately before the meeting.

The Committee on Legislation was also instructed to make such revision of the Constitution and By-Laws as may be necessitated in case the Legislature shall pass the proposed bill providing for State support of the Academy, this instruction to be interpreted as notice of proposed amendment, enabling definitive action at the next annual meeting.

Certificate of Election to Fellowship.

The Secretary was instructed to prepare a suitable certificate to be presented to each newly elected fellow in the Academy.

Appeal from University of Debreczen.

An appeal from the Director of the Geographical Institute of the Royal University of Debreczen (Hungary), under date of December 7, 1920, for "books, used clothes, and even little sums of money" for the desperately needy students of the department, was read by the Secretary. No action was taken by the Academy beyond thus calling the matter to the attention of the individual members.

Scientific Sessions.

The complete scientific program of the meeting follows:

PRESIDENTIAL ADDRESS.

Thunderstorms; especially those of Ohio......................W. H. ALEXANDER

PUBLIC LECTURES.

Hookworm and human efficiency..........................CHARLES A. KOFOID
Scientific work at the Ohio Bureau of Juvenile Research....HENRY H. GODDARD

PAPERS.

1. The new Cleveland Museum of Natural History. (15 min.)....PAUL M. REA
2. The state park situation in Ohio. (15 min.)...........J. ERNEST CARMAN
3. Chronological view of men of science. (7 min.)................J. A. CULLER
4. A peculiar case of stature inheritance. (3 min.).............A. B. PLOWMAN
5. A differential sensitivity theory of time and space and its bearing on evolution. (7 min.)......................................L. B. WALTON
6. The relation of the biologist to public health administration. (15 min.), A. B. PLOWMAN
7. The function of the striae and the origin of bilateral symmetry in the euglenoids. (15 min.) (Lantern).........................L. B. WALTON
8. The geographical distribution of the genera of Opalinidae. (20 min.), (Opaque projection)............................MAYNARD M. METCALF
9. Hemiptera of the Adirondacks. (10 min.) (Lantern).....HERBERT OSBORN
10. Collecting in southern Florida. (10 min.)................HERBERT OSBORN
11. Some studies in Hessian fly emergence. (10 min.) (Lantern)..T. H. PARKS
12. Notes on the habits and life history of Galeatus peckhami Ashm. (5 min.) (Lantern).......................................CARL J. DRAKE
13. A new Ambrosia beetle: notes on the work of Xyloterinus politus Say. (6 min.) (Lantern).......................................CARL J. DRAKE
14. Phylogeny and distribution of the genus Libellula. (20 min.) (Lantern), CLARENCE H. KENNEDY
15. Aids in teaching elementary cytology. (By title)...........Z. P. METCALF
16. The cytology of the sea-side earwig Anisolabis. (15 min.)..S. I. KORNHAUSER
17. Copulation in Planaria maculata. (5 min.)..............R. A. BUDINGTON
18. On the regulative capacity of the neural tube. (15 min.) (Lantern), H. L. WIEMAN
19. The musculature of the head and throat of the Chimaera ogilvyi. (15 min.) (Lantern)...MAE FREIDLANDER
20. New models of the development of the heart in the chick. (20 min.), BRADLEY M. PATTEN
21. Some features of the morphology of the kidney of Necturus. (20 min.), S. W. CHASE
22. Orientation in the cat. (5 min.)......................FRANCIS H. HERRICK
23. Diet of a captive mole. (5 min.)..........................E. L. MOSELEY
24. Additions to the birds of Ohio. (10 min.)...................LYNDA JONES
25. Phagocytoses and clotting in the perivisceral fluid of Arbacia. (10 min.), J. E. KINDRED

26. Further observations as to effect of thyroid substance on plant protoplasm. (5 min.)..R. A. Budington
27. The origin and development of the prairie in North America. (40 min.), (Lantern)..H. C. Sampson
28. The significance of native vegetation in crop production. (35 min.), (Lantern)..A. E. Waller
29. Energy relations of an acre of corn. (5 min.)..............E. N. Transeau
30. Some energy relations of aquatic life and their significance. (10 min.), L. H. Tiffany
31. Contributions to the genetics and cytology of parthenogenetic Taraxaca. (5 min.)..Paul B. Sears
32. Reversal of the sexual state in the Japanese hop. (10 min.)..J. H. Schaffner
33. The occurrence and abundance of certain algae in Lake Erie. (10 min.), Malcolm E. Stickney
34. The census of flowering plants on certain small islands of Lake Erie. (8 min.)..Malcolm E. Stickney
35. Causes and consequences of the irregularities in the glacial border in the Ohio Valley. (30 min. (Lantern).............G. Frederick Wright
36. Explorations in Eastern Bolivia. (20 min.)..................K. F. Mather
37. Some sub-surface rock channels filled with glacial material. (15 min.), J. Ernest Carman
38. A fault-zone breccia in the Bass Island series. (10 min.)..J. Ernest Carman
39. A disconformable contact at the base of the Sylvania sandstone. (5 min.) J. Ernest Carman
40. The Ordovician and Silurial seas of American Arctic and Subarctic regions and the relation of their faunas to contemporaneous seas of European areas. (20 min.)..............................Aug. F. Foerste
41. Some coastal geology of southern Florida. (20 min.)..........G. F. Lamb
42. An interpretation of some Ohio geology. (12 min.)...........G. F. Lamb
43. Richmond Ostracoda of especial interest. (10 min.)........W. H. Shideler
44. Additions to our knowledge of the Arnheim. (10 min.)....W. H. Shideler
45. A Pliocene brackish water fauna near Alexander, La. (10 min.)..E. R. Smith
46. A modification of Hobbs's method of teaching interpretation of geologic maps. (10 min.)..E. R. Smith
47. An embryonic volcano in Adams County, Ohio. (15 min.), Walter H. Bucher
48. Local geology of Cleveland from an economic standpoint. (25 min.), (Lantern)....................................Frank R. Van Horn
49. The reopening and the end of the Linton (Ohio) Coal-measures, fossil-amphibian locality. (10 min.)..............................J. E. Hyde
50. The fauna of the Berea Grit; a recurrent Bedford fauna, and its bearing on the age of the Bedford. (15 min.)........................J. E. Hyde
51. Some psychology applied to Americanization. (20 min.)..Garry C. Myers
52. Scientific direction of childhood—America's greatest social and political responsibility. (30 min.)...........................Herman H. Young
53. Reliability of survey methods in individual diagnosis. (20 min.), Florence Fitzgerald
54. Limiting factors in human behavior. (5 min.)..................A. P. Wise
55. Waste of mental ability in our school system. (10 min.)...Helen Marshall
56. (a) Some studies in progress in the Cleveland School of Education.
    (b) Some data on learning curves. (30 min.).............Garry C. Myers
57. College men in the penitentiary. (20 min.).............Carl Murchison

58. A preliminary report on retroactive inhibition (with particular reference to two conditions). (20 min.)............................E. B. Skaggs
59. The measurement of psychological effects of fatigue and low oxygen. (20 min. (Lantern)....................................C. F. Dockeray
60. Discussion of the legal status of psychology in Ohio State. Discussion led by H. Austin Aikins

DEMONSTRATIONS.

(a) Chromosomal complexes of Anisolabis...................S. I. Kornhauser
(b) Geographic distribution maps for the Opalinidae and their hosts, Maynard M. Metcalf
(c) New models of development of the heart in the chick.....Bradley M. Patten
(d) Chart and data relating to an interesting case of stature inheritance, A. B. Plowman
(e) Multiple ova in Graafian follicles of cat..................Edward L. Rice
(f) Sulphur dioxide injury to vegetation.........................A. E. Waller
(g) Illustrations of euglenoids...................................L. B. Walton

THUNDERSTORMS: ESPECIALLY THOSE OF OHIO.*

WILLIAM H. ALEXANDER
Meteorologist, U. S. Weather Bureau, Columbus, Ohio

I. THUNDERSTORMS IN GENERAL.

1. *Introduction*

The typical thunderstorm, that is, the thunderstorm complete in every detail from its beginning to its ending, has ever held a unique place in the world of human thought and speculation as evidenced by its large and conspicuous place in ancient mythology, by its scarcely less conspicuous place in the history and literature of the race, and by the earnest consideration it has received from the brightest minds of the scientific age. Not only so, but its physical characteristics are such as to assure it a place of real and permanent interest in our present and future thinking along meteorological lines.

We are told upon apparently good authority[1]† that more myths have gathered about the thunderstorm and its phenomena than about any other natural phenomenon, except possibly light and darkness. And we are quite prepared to believe it when we recall the ominous stillness of the air, the darkness of the sky, the lurid glare of the clouds, the majestic roar of the thunder, and the indescribable effects of the highly electrified bodies on the nervés of many people. If these storms inspire so much awe in the human mind in a scientific age—in these days of our boasted intellectual emancipation—with what unspeakable awe must the primitive mind have regarded them! No wonder the thunderstorm was looked upon as a mystery that pressed for solution or explanation. These early "explanations" have come down to us as myths, which, like most myths, are of interest to us chiefly because they constitute the first efforts of the human mind to explain natural phenomena. Then, as now, a thing was regarded as *explained* when classified with other things with which we are acquainted.

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*Presidential address, delivered at the Cleveland meeting of the Ohio Academy of Science.

†For numbers of reference, consult bibliography at close of paper.

We explain, for example, the origin, the progress and the ending of a thunderstorm when we classify the phenomena presented by it with other more familiar phenomena of vaporization and condensation. But primitive man explained the same thing, to his own satisfaction at least, when he classified it along with the well-known phenomena of human volition by constructing a theory of a great black dragon pierced by the unerring arrows of an heavenly archer. As late as 1600, a German writer would illustrate a thunderstorm destroying a crop of corn by the picture of a dragon devouring the produce of the field with his flaming tongue and iron teeth. But we of today no longer regard the thunderstorm as an object of terror or as an unfathomable mystery, but rather as a natural phenomenon of great economic and scientific interest, one in every way worthy of our best and most serious consideration.

The physics and physical features of the thunderstorm are, we believe, fairly well understood. These have been ably and fully discussed by Professor Humphreys of the U. S. Weather Bureau, whose teaching we follow very closely in this discussion. If the thunderstorm produced *only* lightning and thunder, it would be of only relative importance, but it may bring along a whole series of redoubtable phenomena, thus presenting problems of real practical importance—problems the magnitude and importance of which are not always fully appreciated.

2. *Definition*

And now, first of all, let us ask and answer, if we can, this question: "What is a thunderstorm?" Ordinarily, for example, we think of a windstorm as a storm characterized by high and perhaps destructive *winds;* of a hailstorm as one characterized by the production of *hail;* of a snowstorm as one that produces *snow;* of a dust storm as one characterized by a great quantity of flying *dust;* and so, quite properly, we think of a thunderstorm as a storm characterized by *thunder* and lightning. This may not, I grant you, serve as a satisfactory *definition*, but it will, perhaps, be a sufficient *answer* for the time being to the question asked.

It is not necessary in this presence, perhaps, to point out that the "snow," the "wind," the "hail," and the "dust," are in no sense the *cause* of the storm to which they give name.

Nor, so far as known, have the lightning and thunder any influence on the formation, progress and termination of the thunder-storm, although they may and often do constitute the most impressive, spectacular, and even tragic features of the storm. For as Prof. Humphreys well says,[2] "No matter how impressive or how terrifying these phenomena may be, they never are anything more than mere incidents to or products of the peculiar storms they accompany. In short, they are never in any sense either storm-originating or storm-controlling factors."

3. Source of the Lightning

Since we cannot have a thunderstorm without thunder, and cannot have thunder without *lightning*, it seems quite essential to a proper understanding of these storms to get a correct, scientific explanation of the source or cause of the lightning. Oh, yes, we are fully aware of the danger just here—namely, how easily and how quickly one may get beyond his depth when talking about the origin of electricity. We must admit, of course, that we know very little if anything for certain at this point, but then we would like to *appear* to know something about this interesting phase of our discussion. We are deeply indebted to Dr. G. C. Simpson[3] of the Indian Meteorological Department for our best information or knowledge on this point. Dr. Simpson, by numerous observations and laboratory experiments found out a great many extremely valuable things concerning the electricity brought down by the raindrop and the snowflake, and at the same time, by means of a number of well-devised experiments, determined the electrical effects of each obvious process that takes place in the thunderstorm. He found out, for example, that no electrification resulted from freezing and thawing, air-friction, etc., but that when he allowed drops of *distilled water* to fall through a vertical blast of air of sufficient strength to produce some spray,

(1) That breaking of drops of water is accompanied by the production of both positive and negative ions.

(2) That three times as many negative ions as positive ions are released.

"Now," as pointed out by Professor Humphreys[2], "a strong upward current of air is one of the most conspicuous features of the thunderstorm. It is always evident in the turbulent cauliflower heads of the cumulus cloud, the parent, presumably, of all thunderstorm. Besides, its inference is compelled by the occurrence of hail, a frequent thunderstorm phenomenon, whose formation requires the carrying of raindrops and the growing hailstones repeatedly to cold and therefore high altitudes. And from the existence of hail it is further inferred that an updraft of at least eight meters per second must often occur within the body of the storm, since, as experiment shows, it requires approximately this velocity to support the larger drops, and even a greater velocity to support the average hailstone.

"Experiment also shows that rain can not fall through air of ordinary density whose upward velocity is greater than about eight meters per second, or itself fall with greater velocity through still air; that in such a current, or with such a velocity, drops large enough, if kept in tact, to force their way down, or, through the action of gravity, to attain a greater velocity than eight meters per second with reference to the air, whether still or in motion, are so blown to pieces that the increased ratio of supporting area to total mass causes the resulting spray to be carried aloft or left behind, together with, of course, all original smaller drops. Clearly, then, the updrafts within a cumulus cloud frequently must break up at about the same level innumerable drops which, through coalescence, have grown beyond the critical size, and thereby according to Simpson's experiments, produce electrical separation within the cloud itself. Obviously, under the turmoil of a thunderstorm, its choppy surges and pulses, such drops may be forced through the cycle of union (facilitated by any charges they may carry) and division, of coalescence and disruption, from one to many times, with the formation on each at every disruption, again *according to experiment*, of a correspondingly increased electrical charge. The turmoil compels mechanical contact between the drops, whereupon the charges break down the surface tension and insure coalescence. Hence, once started, the electricity of a thunderstorm rapidly grows to a considerable maximum.

"After a time the larger drops reach, here and there, places below which the up-draft is small—the air can not be rushing up everywhere—and then fall as positively charged rain, because of the processes just explained. The negative electrons in the meantime are carried up into the higher portions of the cumulus, where they unite with the cloud particles and thereby facilitate their coalescence into negatively charged drops. Hence, the heavy rain of a thunderstorm should be positively charged, as it almost always is, and the gentler portions negatively charged which very frequently is the case.

"Such in brief, is Dr. Simpson's theory of the origin of the electricity in thunderstorms, a theory that fully accounts for the facts of observation and in turn is itself abundantly supported by laboratory tests and simulative experiments.

"If this theory is correct, and it seems well founded, it must follow that the *one essential* to the formation of the giant cumulus cloud, namely, *the rapid uprush of moist air*, is also the one essential to the generation of the electricity of thunderstorms. Hence the reason why lightning seldom if ever occurs except in connection with a cumulus cloud is understandable and obvious. It is simply because the only process that can produce the one is also the process that is necessary and sufficient for the production of the other."

4. Turbulence of the Cumulus Cloud.

That the large cumulus clouds, especially those that produce thunderstorms, are exceedingly turbulent within with violent vertical motion, as demanded by the theory just outlined, is evident to even the casual observer. Furthermore the testimony of those balloonists who have had the trying ordeal of passing through the heart of a thunderstorm confirms the facts of observation. Since these are the only clouds, apparently, characterized by this high degree of turbulence, it may be well to pause a moment and ask why these motions—motions which, in the magnitude of their vertical components and degree of turmoil, are never exhibited by clouds of any other kind nor are they met with elsewhere by either manned, sounding or pilot balloons. Without going into very great detail, it may be pointed out, as has been done by von Bezold[4], that the heat liberated by the sudden condensation from a state of supersaturation, and also from the sudden congelation of undercooled cloud particles, would cause an equally sudden expansion of the atmosphere, resulting in turbulent motions analogous to those observed in the large cumulus clouds.

This, however, is not sufficient to account for all the observed facts, since it is not clear just how either the condensation or the congelation could suddenly take place throughout a cloud volume great enough to produce the observed effects. We must, therefore, look for some other explanation, and this we shall probably find, *in the difference between the actual temperature gradient of the surrounding atmosphere and the adiabatic temperature gradient of the saturated air within the cloud itself;* or, in other words, the cause of the violent up-rush and turbulent condition within large cumulus clouds is, presumably, the difference between the temperature of the inner or warmer portions of the cloud itself and that of the surrounding atmosphere at the same level.

5. *Causes of Convectional Instability.*

As we have just tried to show the *sine qui non* of the thunderstorm is the *rapid* vertical convection of *moist air;* the up-rush must be *rapid* and the air must be *moist;* one without the other is not sufficient. We may have, for example, a *very* rapid convection over a desert region but there being no moisture there will be no cloud-formation and therefore no thunderstorm. On the other hand we may have air ever so humid but if the movement upward is too gentle not even a cloud may result, but if a cloud, certainly no thunderstorm. It is obvious, therefore, that we must have both "rapid convection" and "moist air."

This leads us to a consideration of the conditions under which the vertical temperature gradients necessary to this convection can be established. These conditions are, according to Prof. Humphreys, three in number, namely:

(1) A strong surface heating, expecially in regions of light winds.
(2) The over-running of one layer of air by another at a temperature sufficiently lower to induce convection.
(3) The under-running and consequent uplift of a saturated layer of air by a denser layer.

Of these three conditions, the first mentioned—"strong heating surfaces"—is, for obvious reasons, of most frequent occurrence over the land surfaces of the earth; number two is also of frequent occurrence on land and is, perhaps, well nigh the sole cause of thunderstorms on the ocean. Number three is by far less frequently the cause of thunderstorms than the other two, for while the actual *under-running* is of rather frequent occurrence, it seems probable that only occasionally is the uplift of sufficient magnitude to cause a thunderstorm.

6. Periodic Recurrence of Thunderstorms.

Keeping in mind the conditions or factors absolutely essential to the formation of a thunderstorm, we are well prepared to consider, perhaps in a measure to anticipate, the periodic recurrence and distribution of thunderstorms, for while it is possible, of course, for a thunderstorm to occur on any day at any hour, yet the fact is, and for obvious reasons, the day has its period of maximum thunderstorm activity, the year its maximum period, and there is some evidence of irregular cyclic periods of maximum activity, each maximum depending upon the simple facts that the more humid the air and the more rapid the local vertical convections the more frequent and also the more intense the thunderstorms.

Taking the *day* as our unit, we find the period of maximum thunderstorm activity is not the same over the land as over the ocean. Vertical convection of the atmosphere over the land is most pronounced, of course, when the surfaces are most heated, namely, in the afternoons; hence the inland or continental thunderstorm occurs most frequently, in most places, between 2 and 4 P. M. Over the ocean, however, the temper ature gradients that are most favorable for rapid vertical convection are most frequent during the early morning hours, and therefore thunderstorms usually occur on the ocean between midnight and 4 A. M. If we take the *year* as our unit, we find, for reasons that will readily occur to all, that thunderstorms are most frequent, over the land, when the surface heating is at a maximum, in middle latitudes in June and in the higher latitudes in July or August. Over the ocean, however, the thunderstorm is most frequent in the winter months.

Furthermore, since the thunderstorm is vitally associated with rainfall and high temperature, it must follow that a *cycle* of warm, wet years would give a maximum of thunderstorms and a cycle of cold, dry years a minimum.

We have the key to the *geographical* distribution of thunderstorms in the conditions essential to their production, and while it is safe to say that the thunderstorm, in one form or another, does occur at some time or other in all parts of the earth, yet from what we know of the meteorological conditions ordinarily prevailing over the various portions of the earth, we are very sure that it is very rare over large areas and may never occur in some regions. In the United States[5], for example, we find two centers of maximum thunderstorm activity, one over Tampa, Florida, and the other over Santa Fe, New Mexico. In the ten-year period, 1904-1913, 944 thunderstorms were recorded at Tampa and 710 at Santa Fe. Tampa is near sea-level and Santa Fe is about 7,000 feet above the sea.

7. *Classification of Thunderstorms.*

One is impressed with the very great variety and many variations met with in the study of these storms. This is true whether one is considering the attendant circumstances, the varying degree of intensity exhibited by them, the frequency of occurrence, the resulting effects, the distribution through the day, the year, or over the earth's surface, or whether one is considering the factors operating to produce and maintain these storms. Variety everywhere!

At one time, and not so long ago, it was thought that all thunderstorms were local phenomena and were therefore not subject to any general law. In an important sense the thunderstorm is a local phenomenon but the forces operating to produce many of them are far from local. It is now known that a majority of these storms travel in a definite direction and are therefore moving under a general law. In general, with respect to the producing causes or conditions out of which they grow, thunderstorms may be divided into (1) local or "heat" thunderstorms, and (2) the cyclonic thunderstorms, or "thundersqualls." Or, if we wish to be a little more exact or "scientific," we may follow Professor Humphreys and make five classes, namely, (1) the "heat" or local, (2) the cyclonic, (3) the tornadic, (4) the anti-cyleonic, and (5) the "border," thunderstorm. The significance of this classification will be pointed out later in connection with the illustrated portion of this lecture but it seems appropriate at this time to refer to Durand-Greville's famous theory of "the squall zone" in connection with cyclonic thunderstorms. He holds that "cyclonic thunderstorms"—and that means all except the "local" or "heat" thunderstorm—are but an accessory result of a body of extremely complex phenomena—an organism someone has called it[6]—the *squall*, which is subject to fixed laws and forms an integral part of certain lows. This so-called "squall zone" in which, according to Durand-Greville[7], nearly all "cyclonic" thunderstorms, or as he calls them, "thundersqualls," occur, starts some where near the center of the barometric depression or "low" and usually extends out to its boundary, thus having a length of a thousand miles or more, while its width may vary from 10 to 60 miles or more. This zone moves, advances or recedes, with the "low" of which it is a part, as a rule remaining parallel with itself. Should the "low" remain stationary, the squall zone may, and usually does, swing round the center. The passage of the "squall zone" over any given place, shown by the familiar "squall hook" of the barograph trace, is attended by the concomitant production of certain phenomena that occur only within the limits of the zone. They begin at the moment the "squall front" of the squall zone reaches the place of observation, they rapidly attain their maximum intensity, and then gradually weaken and finally die out as the rear of the zone passes and normal conditions become established. These accompanying phenomena may be more or less numerous, thus giving rise to a variety of "squalls," each characterized by its appropriate phenomena. These squalls have been classified by Durand-Greville as follows, viz.:

Durand-Greville's Classification of Squalls[8]

1. Sudden increase in wind velocity	White squall	Wind squall	Rain, hail, or snow squall	Thunder squall
2. Sudden change in wind direction				
3. Sudden rise in pressure				
4. Sudden fall in pressure				
5. Sudden rise in relative humidity				
6. Rapid increase in cloudiness				
7. Downpours of rain hail snow				
8. Lightning and thunder				

The basis of this classification is, as you see, increasing complexity. Note also that the phenomena observed during the passage of a squall are actually the results of two causes, one of these, the "squall wind," is purely *dynamic*, pre-existant, and may be of distant origin; the other is the local condition of the atmosphere and is *static*.

8. The Mechanism of the Thunderstorm.

Thus far we have considered the thunderstorm in a more or less general way—its definition, its causes, its recurrence, its distribution, its relation to areas of high and low pressure, etc. Let us now consider *a* typical thunderstorm in actual progress and note its mechanism and some of its more important phenomena. Just here the slide would be very helpful but we shall content ourselves just now with the bare mention of some of the things that one may look for in the well-defined thunderstorm. Among these may be mentioned the winds, the squall cloud, the pressure, the temperature, the humidity, the rain, the hail, the so-called "rain-gush," the rate of advance of the storm, the lightning, and the thunder.

First, the thunderstorm winds must be carefully considered if one is to understand fully the mechanism of the thunderstorm itself. As every one knows, as a thunderstorm approaches a given place the wind at that place is generally light and from a direction that carries it across the path of the approaching storm, that just before the rain begins the wind begins to die down, almost to a calm, and to change its direction. When this change is complete it blows for a few moments, rather gently, directly toward the nearest portion of the storm front, and finally as the rain is almost at hand, there is a sudden change of direction and the wind now comes, often in violent gusts, directly away from the storm and in the direction the storm is moving, a direction quite different from the original direction of the wind. As a rule these strong gusts of wind last through the early part of the storm only and then follow gentle winds again, at first following the storm but after an hour or so they blow from the same general direction as the original surface winds. Now, as we have tried to show, the thunderstorm is the child of a cumulus cloud and the cumulus cloud is the child of a vertical convection which results from a more or less super-adiabatic temperature gradient. This gradient may be established in one of three ways, as above pointed out. Now, inasmuch as the passage of a cumulus cloud overhead, however large, so long as rain does not fall from it, does not materially disturb the surface winds, in other words, does not bring on any of the familiar gusts and other thunderstorm phenomena, we must infer that in some way the rain is an important factor both in starting and maintaining the winds we have just noted. On the other hand we cannot assume that the rain is the whole cause of these winds for they do not accompany other and ordinary showers, however heavy the rainfall.

The "rain-gush" or heavy downpour after a heavy clap of thunder has often been misunderstood and has been made to serve as a proof of the claims of the so-called "rain-makers." The fact is the rain is the cause of the thunder or lightning, and not the thunder the cause of the heavy rain.

Then there is the *lightning* in its various forms, the "streak" lightning, the so-called "rocker" lightning, the "ball" lightning, the "sheet" lightning, the "beaded" (?) lightning, the "return" lightning, and some people say the "dark" lightning, and so on. To discuss all these would carry us far beyond our limit. Then there is the question of the temperature along the path of a lightning discharge, how does the lightning render the atmosphere through which it passes luminous, etc. Perhaps no one knows the answer to these questions but it is very certain that the temperature along the path of the lightning discharge is very high from the fact that it sets fire to many objects, such as buildings, that fall within its path. Just how the lightning discharge renders its path through the atmosphere luminous is not definitely known. Of course it does make the air along its path very hot but no one so far as I know has ever succeeded by any ordinary means in rendering oxygen or nitrogen luminous by heating. It must be therefore, that the luminosity is due to something besides high temperature, probably, according to Prof. Humphreys, to "internal atomic disturbances induced by the swiftly moving electrons of the discharge." The spectrum reveals to us the interesting fact that lightning flashes are of two colors, white and pink or rose. The rose-colored flashes, when examined in the spectroscope, show several lines due to hydrogen, which of course are due to the decomposition of some of the water along the lightning path. The duration of the lightning discharge is exceedingly variable, ranging from 0.0002 second for a single flash to, in rare cases, even a full second or more for a multiple flash consisting of a primary and a series of subsequent flashes. The lightning discharge is direct, not alternating, as shown by the fact that the lightning may operate telegraph instruments, may reverse the polarity of dynamos, both of which requires a direct current.

The length of the lightning streak also varies greatly. When the discharge is from cloud to earth the length is seldom more than 2 or 3 kilometers, but when from cloud to cloud may be 10 to 20 kilometers (6 to 12 miles). The path of the lightning discharge may extend from the cloud to earth, from one portion to another of the same cloud, or from one cloud to another cloud. Obviously the second case is of the most frequent occurrence, that is, from the upper to the lower portion of the same cloud; from cloud to earth is next in point of frequency, and from cloud to cloud, relatively rare. Sometimes the discharge from cloud to earth may include in its strange and tortuous path objects that have not sufficient conductivity to carry it and as a result of the sudden and excessive heating many very freakish things may be done, such as shingles blown off, chimneys shattered, trees stripped of their bark or splintered, wires fused, even holes melted through metal, etc. Then there are certain chemical reactions resulting from these electrical discharges that play an important part in the economy of nature. For instance the health-giving ozone of the atmosphere is greatly increased by the passage of a thunderstorm, and even the fertility of the soil may be increased by the production of considerable quantities of ammonia and soluble salts.

Perhaps, a word or two should be said regarding the *danger* to life incident to the passage of a thunderstorm. That there is danger, even great danger at times, is abundantly shown from the tragic statistics of deaths each year from this cause. While it is not possible, perhaps, to remove this danger, it is possible to reduce it, chiefly by avoiding the points of greatest danger. In general, it is safer inside than outside of a house, especially if the house has a well-grounded rod or metal roof; it is also safer in the valley than on a hill or elevated portion of land, this because the chance for a cloud-to-earth discharge varies inversely as the distance between them; it is also very unsafe to take refuge under a tree and the taller the tree the greater the danger. No tree is immune but those trees having an extensive root system or a deep tap-root are most apt to be struck because they are the best grounded and therefore offer the least electrical resistance. Then again if one is caught out of doors and is exposed to a violent thunderstorm it is best so far as danger from lightning is concerned, to let one's clothes get soaking wet, because wet clothes are much better conductors and dry clothes much poorer conductors, than the human body. It might even be advisable to lie flat on the wet ground, undignified as this may be. For any given locality, the lower the cloud the greater the danger; hence, when the humidity is high it is favorable for a dangerous storm, since the cloud will form at a low level and the rain is apt to be very abundant. For the same reason a winter storm is likely to be more dangerous than a summer storm of equal intensity.

And now how do we account for the *thunder*—that particular feature that gives name to our storm? It has taken quite a while to answer this question satisfactorily. Many very silly theories still persist. The electrical discharge, the "lightning," furnishes the key to the explanation. The sudden and intense heating of the air along the path of the discharge causes it to expand suddenly and violently, sending out from every part of its path a steep compression wave, which, as we understand it, is the real cause of the thunder. The "rumbling" that sometimes follows is due, chiefly perhaps, to the inequality in the distances from the observer to the various portions of the lightning's path, to the crookedness of the path, to a succession of discharges, and to some extent to reflection under favorable conditions. The distance to which thunder may be heard varies from 7 to 15 miles.

9. *Forecasting the Thunderstorm.*

The forecasting of conditions favorable for the formation of thunderstorms one or two days in advance is comparatively easy but to say, even a few hours in advance, that a thunderstorm will occur at a given place, at or about a given time, is, to say the least, a hazardous venture. It is only after the storm has actually begun and its direction and rate of movement have been determined, can one speak with even a small degree of assurance. As every one knows, a storm may occur, in fact several of them, in sight of the observer and yet not at the place of observation. Then besides the thunderstorm is of a very limited duration; it may, at the very most, last twenty-four hours, but as a rule a very few hours will exhaust it. It is only when this type of storm assumes the character of a tornado that knowledge of its approach becomes really important.

10. The Thunderstorm and Excessive Precipitation.

Another thing that gives to the thunderstorm economic importance is the fact that from 66 to 100 per cent of all instances of excessive precipitation in the United States occur as the result of or in connection with thunderstorms[9]. Some places, like Bismark, Denver and Sante Fe, excessive precipitation never occurs except in connection with thunderstorms. Furthermore, the records will show that practically all cases of remarkable downpours of rain or hail occur in connection with these storms.

II. THUNDERSTORMS IN OHIO.

1. Introduction.

Needless to say, the thunderstorms of Ohio do not differ in any essential respect from those we have been discussing. Our chief and perhaps only excuse for referring to them at this time and in this manner is to make an occasion to call the attention of the Academy to a piece of work accomplished in Ohio that, so far as we know, is the only one of its kind in this or any other country, namely an intensive study of thunderstorms over a limited region through a period of one year. The purposes were to determine as far as practicable the origin, the distribution, the number, the frequency, the extent of territory covered, the attending phenomena, etc., of these storms, and if possible, trace the history of each individual thunderstorm that entered or originated in the state of Ohio, during the year 1917.

2. The Plan.

Our plan was to secure at least one observer in each township in the State but as the work was to be purely gratuitous we were not able to interest one person in each of the 1357 townships. Our total enlistment was about 730 volunteer observers, about 130 co-operative observers and the six regular Weather Bureau stations in the State. We also received some assistance from the telephone and telegraph companies in the State and even dealers in lightning rods.

3. *Forms and Instruction.*

Each observer was then supplied with full instructions and a suitable card on which to make his report of each storm. This form called for the exact date and time of the storm, the exact location of the observer, time first, loudest and last thunder was heard, direction the storm moved, time rain began and ended, time hail began and ended, direction of wind before and after the storm, etc. The weakness of the plan was, of course, in the fact that it was dependent upon voluntary service and as was to have been expected, some observers failed us at the critical moment, so that we were not always sure we had the complete history of each storm. However, we assembled quite a mass of thunderstorm data and these have been charted and otherwise prepared for publication.

3. *A Resume.*

Among the many interesting facts brought out in the special study of thunderstorms in Ohio during the year 1917, may be mentioned, briefly, the following:

(a) Thunderstorms in Ohio are incident to the *passage* of those cyclonic areas (see M. W. R., Supplement No. 1) that move directly over or just north of the State, and to the *approach* of those that move just south of the State. The first group includes the Alberta, the North Pacific, the Rocky Mountain and probably the Central and Colorado types; the second group includes the South Pacific and the Texas types, especially those that follow a northeasterly course.

The passage of the Alberta type, especially in the late winter or early spring months, will cause thunderstorms in Ohio when the wind-shift line, or "squall line," is pronounced, and extends in a north-south, or a northeast-southwest direction. These thunderstorms will set in slightly in advance of this line and will continue until it has passed. See weather map of January 31, 1917, 7 A. M. The passage of the North Pacific, the Northern Rocky Mountain, the Central, and the Colorado types, will cause thunderstorms in Ohio only when an area of high pressure prevails over the eastern Lake Region or New England. See weather map of April 17, 1917, 7 A. M. As these types are usually followed by a high pressure area from the northwest of more or less intensity and therefore move with considerable rapidity, the thunderstorms incident thereto are apt to be of short duration and are seldom of a violent character.

But to the approach of the South Pacific and Texas types is to be attributed by far the greater portion of the thunderstorms in Ohio. These types prevail from early May into late October. As a rule thunderstorms will set in over the western part of the State when the center of the "low" reaches Missouri or southern Illinois and will probably become general over the State. These cyclonic types often bring thunderstorms of a very violent nature. When the "low" passes over the northwestern corner of the State, thus forcing the isotherms far northward of their normal position, and is followed by a "high" of moderate intensity, hailstorms are likely to occur with the shift of the wind—passage of the squall line—and subsequent increase in pressure. See weather maps of March 10 and 11, 1917. The position of the Atlantic high does not seem to have any material effect on the rain-producing characteristics of these "lows." When the path of these cyclonic types suddenly curves to the north and passes into the Lake Region from northern Indiana or Illinois, thunderstorms are likely to occur in Ohio both on the approach and the passage of these areas. Normally, however, their passage just over or just south of the State is followed by brisk westerly winds, clearing weather and falling temperature.

The East Gulf and South Atlantic types gave rise to no thunderstorms in Ohio during the year 1917.

(b) The data seem to show certain centers of maximum activity and storm-frequency. The southwestern part of the State is certainly the most favorable portion for the development of the tornado as all tornadoes of consequence in the history of the Bureau have occurred in that section.

(c) Thunderstorms were reported on 169 days, midnight to midnight. Of these 169 days, thunderstorms occurred in the forenoon only on 22 days, on the afternoon only on 80 days, on both forenoon and afternoon on 63 days, on 9 days the storm began in the forenoon and ended in the afternoon, and on 2 occasions the storm began on the afternoon or evening of one day and ended in the early morning of the following day. Note that the afternoon thunderstorm is about four times as frequent as the forenoon, that the number of days with thunderstorms both morning and afternoon is quite large, that the number of days on which the storm begins in the forenoon and continues into the afternoon is quite small and the number beginning in the afternoon or evening and continuing beyond midnight is smaller still.

The reports further show that at leats 31 persons were killed during the year by lightning, 70 others more or less injured; in addition, a large number of animals were killed and much property destroyed. We have no reliable figures as to how many times the lightning actually struck but we learn from the report of the State Fire Marshal that 215 fires were started during the year as the result of a lightning stroke, destroying property valued at about $370,000. The 215 objects damaged or destroyed were classified as follows: 137 barns, 53 dwellings, 4 churches, 4 sheds, 4 warehouses, 2 haystacks, 2 oil tanks, 1 dry cleaning establishment, 1 hotel, 1 livery stable, 1 school house, 1 straw stack, 1 manufacturing establishment and 2 mercantile buildings. The Fire Marshal's office takes no note of lightning strokes that do not start a fire or cause the loss of human life. These fires were distributed through the months as follows, viz.: February, 5; March, 6; April, 5; May, 33; June, 27; July, 45; August, 66; September, 17; October, 11; January, November and December, *none*.

Another item of considerable interest, perhaps, is that about 95 per cent of the objects struck were wet at the time and rain was falling, leaving only about 5 per cent that were dry and struck when no rain was falling. In one case, the burning of a barn near Conneaut, Ashtabula County, March 26th, the report seems to indicate that snow was falling at the time of the stroke that caused the fire.

Another thing: The days on which thunderstorms are general over the State are relatively few. Of the 169 thunderstorm days in 1917, on 7 days only were thunderstorms general; on 11 days they covered about three-fourths of the State; on

23 days about one-half; on 17 days, nearly half the State; on the rest, they were local and limited.

As intimated above, the publication of this report (Thunderstorms in Ohio in 1917) has been and is being delayed on account of lack of the necessary funds.

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FOOD OF THE COMMON OHIO DARTERS

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INTRODUCTION.

This paper constitutes one unit of a report of a fish survey of Ohio undertaken by the Ohio Bureau of Fish and Game and directed by Professor R. C. Osburn, of Ohio State University. It was the main purpose of this survey to determine the status of the game and food fishes in the various waters of the state. In the environmental conditions responsible for the production of game fishes the food plays an important role and in order to have all the factors governing the food conditions it is necessary to determine also the food and feeding habits of those animals which are themselves used as food by the game fishes. During their younger stages perch and darters, as well as the young of many other kinds of fish, furnish food for the young, yearling and older basses. A report has already been made upon the food and feeding habits of the young perch (Turner, 1920) and this report offers a similar study of the darters.

A part of the work was done at the Lake Laboratory of Ohio State University at Put-in-Bay during July of 1919 and the writer is greatly indebted to Director R. C. Osburn, who with his keen interest and long experience in fish problems, lent encouragement and advice. During the summer of 1920 Professor Osburn, L. H. Tiffany, E. L. Wickliff and W. C. Kraatz of Ohio State University, and the writer made extensive collections from all the larger lakes and reservoirs of the state as well as from some of the streams of central Ohio. Several thousands of darters were collected, comprising eleven different species and ranging in size from ten to one hundred millimeters. Six hundred and twelve of these covering a wide range in locality, kind of habitat, date of capture and age of individual were examined.

METHODS.

All the measurements of length include the distance from the base of the caudal fin to the tip of the jaw or snout.

Very few specimens were examined in a fresh condition, nearly all being preserved in strong formalin as soon as taken.

Various kinds of seines were furnished by the Bureau of Fish and Game and practically all the fish were taken by seining.

In determining the quantity and character of the food the stomach and intestine were dissected out with the aid of a binocular microscope, the contents removed and, so far as possible, identified. A compound microscope was also employed for the identification of smaller objects, after which quantitative estimates of the various articles of food were made.

FOOD OF EACH SPECIES.

There is a general similarity in the food of the different species. The most typical feed almost exclusively in their younger stages upon entomostraca and minute midge larvæ, later increasing the amount of midge larvæ at the expense of the entomostraca. It is worthy of note that larger specimens of midge larvæ are taken as the fishes increase in size. Still later the young fishes turn to larger insect larvæ and this is their staple adult food. Forbes shows that the younger fishes of most families pass through these stages and then become more specialized as adults, eating fish, molluscs, vegetation or even one-celled organisms. Several variations from the generalized food habits occur among the darters and the details of such variations will be taken up in the discussion of each group.

A. **Percina caprodes** Rafinesque.

There is no question but that *Percina caprodes* and *P. caprodes* variety *zebra* appear in the collections but no distinction has been made here. Specimens were taken from Lake Erie, mainly at Put-in-Bay, many of the streams and from most of the inland lakes of the state. It was the most common and widely distributed of the whole group of darters. The specimens have been divided into three groups, those from Lake Erie, those from the streams and those from the inland lakes, as these seem to offer rather definite units of habitat.

TABLE 1.

Food of *Percina caprodes* from Lake Erie.

Length in mm.	23	24	25	26	27	28	29	30	32	33	34	36	37	39	40-50	50-60	60-70	70-80
No. examined	1	8	8	10	16	8	4	4	2	1	4	1	2	2	10	24	22	6
Articles of diet:																		
Copepoda	100.	95.	70	82.5	60.6	53.6	77.5	85.	95.	70.	25	60.	87.	5.	10.7	7.7	4.2	
Cladocera		2.5	6.	10.	6.2	12.8	20.	5.			15.	40.	5.		27.7	.2	2 2	
Ostracoda				+		+												
Midge larvae			3.2	6.	8.5	8.2		10.			10.			75.	46.2	54.1	34.	21.
Amphipods		2.5				6.2									.5	18.3	16.8	40 1
May fly larvae			10.	1.5	6.2	7.55	1.5				50.		8	20	1.	13.4	34 8	
Other insect larvae															12.5	2.5	4.5	20.
Snails																	.7	
Isopods																	.9	
Fish remains										10.					1.2			
Fish eggs																	.1	
Flat worms			1.			.2	.2									.6		
Round worms			.25				.2								.2	.5		
Annelid worms					4.5	11.2	.6		5.	20.								10.
Nauplius larvae			.25			.25												
Plant remains																3.2	1.8	6.3
Sand and silt																.5		2.6

TABLE 2.

Food of *Percina caprodes* from inland lakes.

Length in mm.	30-35	35-40	40-50	50-60	80-90	90-100
No. examined	1	4	3	2	4	2
Articles of diet:						
Copepoda			30.6	1.		
Cladocera		22.5	16.6		1.3	
Ostracoda						3.
Midge larvae	60.	29.5	29.3	96.5	26.6	7.5
Amphipods					6.6	20.
May fly larvae	38.	11.75	3.3	1.5	30.6	5.
Beetle larvae		15.			13.3	7.
Caddis fly larvae					6.	50.
Other insect larvae			20.2			
Fish remains		11.75				
Round worms	2.				4.	
Plant remains		9.5			4.3	.5
Bottom debris				1.	7.3	7.

TABLE 3.

Food of *Percina caprodes* from streams.

Length in mm.	25-30	30-35	35-40	40-50	50-60	60-70	70-80
No. examined	1	2	2	1	2	3	1
Articles of diet:							
Copepoda	15.		2.5		1.	2.4	
Cladocera			1.5		.5	1.	
Midge larvae		66.	90.	100.	52.	47.6	
May fly larvae	80.	34.	5.		45.	20.	88.
Caddis fly larvae					.5	11.4	11.
Snails						16.6	
Fish eggs	5.						
Flat worms						.3	
Sand and silt			1.		1.	.7	1.

The record of the Lake Erie specimens shows that there are three rather well-defined periods in the food habits. The youngest subsist almost entirely upon entomostraca although minute amphipods and midge larvæ are also taken to a limited extent. During the second period amphipods, insect larvæ and entomostraca are eaten, with the insect larvæ and the amphipods gradually predominating. In the last stage the diet becomes very complex with the larger insect larvæ and amphipods furnishing the larger proportion of the food while the quantity of entomostraca becomes negligible. Although the quantity of entomostraca definitely decreases, a few are eaten even by the largest fish and an occasional individual is found which has eaten little else.

The specimens taken from the inland lakes were fewer in number but were more developed, none being smaller than 30 mm. The food habits of this group closely parallels that of the Lake Erie group but there is one outstanding, if minor, difference. Entomostraca do not play nearly so constant a part in the diet although there is a larger proportion eaten by the smaller fishes. It is to be noted that the waters of the inland lakes are much more concentrated in their production of insect food than those of Lake Erie and it is possible that the Lake Erie fish are compelled to rely upon Entomostraca in the absence of insect food.

Some interesting variations in food habits are offered by the fishes from the streams. 1. The food is less varied in the stream fish. 2. Entomostraca are eaten constantly but in a very small proportion while midge and May fly larvæ furnish almost the whole food in many cases. 3. Amphipods are wholly lacking in the food of the stream fishes. 4. There is a proportionately large amount of molluscan food taken. 5. Planorbis and Physa are the principal snails eaten by the specimens from Lake Erie while Ancylus is the only snail taken by the stream fishes.

Summary of Food Habits in Percina caprodes.

1. Younger specimens subsist mainly upon entomostraca. 2. Insect food and entomostraca are taken by the intermediate individuals. 3. The larger specimens have a more complicated diet but entomostraca are continued as a constant though small item and insect larvæ form the principal constituent. 4. Specimens from the inland lakes vary somewhat from the course followed by the Lake Erie specimens. 5. Fishes from the streams differ markedly in their food habits from those from Lake Erie and the inland lakes.

B. **Diplesion blennioides** Rafinesque.

This darter is well distributed and great numbers of them were taken in the streams throughout the state. A few of the older ones and a fair number of the younger ones were taken in the vicinity of the Bass Islands of Lake Erie. A few were taken from the inland lakes. Tables 4 and 5 illustrate the comparative food habits of the Lake Erie and the stream specimens. The data concerning those from the inland lakes was so scant as not to warrant a table.

TABLE 4.
Food of *Diplesion blennioides* from Lake Erie.

Length in mm.	15-20	20	21	22	23	25	28	33	36	55
No. examined	3	2	2	4	2	8	6	2	2	1
Articles of diet:										
Copepoda	3.33									
Cladocera	13 33					1				
Ostracoda						.5				
Midge larvae	80.	100.	100	70.	90.	85.	71.6	90.	100.	100.
May fly larvae				30.			6 4			
Beetle larvae					10	12.	22.	10		
Filamentous algae						5				
Stones and silt	3.34					1.				

TABLE 5.
Food of *Diplesion blennioides* from streams.

Length in mm.	20-25	25-30	30-35	35-40	40-50	50-60
No. examined	9	11	3	4	8	3
Articles of diet:						
Copepoda	.33	8.17		.5	1.25	
Cladocera	.24				1.	
Ostracoda					3.75	
Midge larvae	85 55	63 27	66 66	97.5	42.35	23.33
May fly larvae		14 09	30.	2.	14	50 8
Beetle larvae					2.5	
Caddis fly larvae	.55				12.25	23.33
Snails		.9				
Fish remains		4 68	3 34		1 25	
Mites		.09				
Annelid worms					11.25	
Bottom debris	13.33	8.90			10.4	2.64

Midge larvæ and may fly larvæ seem to furnish the main articles of diet for both old and young. The very young show a tendency to incorporate more of the entomostraca in their diet and it is possible that specimens smaller than any of these taken may eat still a larger percentage of entomostraca. In the latter regard there is a slight resemblance to *Percina caprodes* but the change from entomostracan food to insect food is not nearly so well marked in *Diplesion.* Although amphipods were abundant in the localities seined, few appear in the food of *Diplesion.* Two specimens only from Buckeye Lake had eaten more than fifty per cent of Amphipods.

The specimens taken from the streams showed a more varied diet than those from the lakes but the tendency to favor midge and may fly larvæ is still apparent. Silt and debris appear in large quantities in the stream specimens but these may have been taken accidentally while the fish were securing other food.

Summary of food habits in Diplesion blennioides.

1. The earliest stage, which is marked by the consumption of entomostracan food in *Percina caprodes*, is poorly shown in *D. blennioides.* 2. May fly larvæ and midge larvæ constitute the main articles of diet for both smaller and larger specimens. 3. Specimens from streams tend to show a more complicated diet.

C. **Boleosoma nigrum** Rafinesque.

Specimens of this active little fish were taken in nearly every stream and inland lake examined. Tables have been prepared for those from the streams and for those from the lakes, but the habits are so uniform that little of difference is offered in such tables. The younger specimens compare favorably with those of *Percina caprodes* in their selection of entomostraca and minute midge larvæ for food and in their gradual relinquishment of this food to take up may fly larvæ and larger midge larvæ. May fly larvæ and midge larvæ are the only animals eaten by many and these forms are not wholly lacking in the food of any. The constant occurrence and large quantities of silt and debris indicate a selection of this material by the fish for food.

TABLE 6.

Food of *Boleosoma nigrum* from inland lakes.

Length in mm.	20–25	25–30	30–35	35–40	40–50
No examined	6	6	10	9	1
Articles of diet: Copepoda	6.33	6.09	10.1	4.77	30.
Cladocera	20.16	10.33	21.3	11.66	
Ostracoda	2.33		3.1	.83	
Midge larvae	50.83	54.33	44.5	71.66	10.
Amphipods	6.66				
May fly larvae	3.33	10.	2.0	5.55	
Caddis fly larvae					10.
Fish remains	3.33	9			
Flat worms			1.2		
Round worms		2.	6	1.33	
Filamentous algae	.5	1.33	.6	.2	
Diatoms	1.7	26			
Desmids	33				
Sand and silt	1.5	6.66	16.6	4.	50.

TABLE 7.

Food of *Boleosoma nigrum* from streams.

Length in mm.	15–20	20–25	25–30	30–35	35–40	40–50	50–60
No. examined	4	17	20	10	4	4	1
Articles of diet: Copepoda	40.25	19.04	18.75	12.5	8.25	4.25	
Cladocera	8.25	12.4	7.1	1.5	7.25	1.5	
Ostracoda		2.64	.4	1.	1.25		
Midge larvae	35.75	49.11	50.9	52.3	60.	85.75	40.
May fly larvae	2	2.94	2.5	12.8			60.
Beetle larvae					7.50		
Caddis fly larvae			.5			1.75	
Snails		.58	1.5	2.			
Fish remains		.3	.5	1.5			
Flat worms		.3	1.5				
Round worms		.82	.85	.5			
Mites		1.					
Rotifers		.17					
Filamentous algae				.8			
Bottom debris	13.75	10.7	15.5	15.1	15.75	6.75	

Summary of Food Habits in Boleosoma nigrum.

1. Entomostraca and minute midge larvæ constitute the chief food of the young. 2. Midge larvæ of larger size and may fly larvæ gradually supplant the entomostraca as the fish increase in size. 3. Organic and inorganic debris forms an important food item in fishes of all ages. 4. Lake and stream habitats do not affect the food habits differentially.

D. **Cottogaster copelandi** Jordan.

Members of this species were taken only from the Bass Island region of Lake Erie where it was the most universally distributed of all the darters. The food habits resemble those of some of the minnows in that a large amount of vegetable material and silt enter into the food. Midge larvæ and may fly larvæ are most commonly taken, but single specimens have been taken whose stomachs were entirely filled with debris and algæ. Another distinctive point is the negligible quantity of entomostraca occurring in the food. This fact, together with the fact also that ostracoda occur frequently, points toward a strict bottom feeding habit. It is also notable that there is little difference in the diet of younger and more mature fish.

TABLE 8.

Food of *Cottogaster copelandi.*

Length in mm.	23	28	30	31	32	34	35	36	37	38	39	40	41	42	44
No. examined	1	1	1	2	3	2	5	3	5	5	5	5	4	5	2
Articles of diet: Copepoda				2 5	+		19								
Cladocera					+	15	1.				+		3 1		
Ostracoda		3.					1.			8.	1.	14.2	.7		
May fly larvae	50.			45.	20.	35.	19.	....	24	28.	18.	21.4	11.	20	75.
Amphipods					5.6										
Midge larvae	50.	97.	85	27.5	69 4	40.	44.	62 6	35.	31.4	23.	28.4	7.	20.	25.
Beetle larvae						10.	4	1							
Fish remains			10.					5.		3.	6.	8.			
Fish eggs								3.3	11.	4.6	24.	2.		46.	
Mites				5.											
Filamentous algae			5.	5.				13.1	5.	2.	1.	14.	+	3.	
Bottom debris				15	5.		12.	15.	25.	23.	27.	12.	78.2	11.	

Summary of Food Habits in Cottogaster copelandi.

1. Midge larvæ and may fly larvæ are the principal articles of diet. 2. Comparatively large quantities of algæ and bottom debris are eaten. 3. Entomostraca are taken only in very small quantities.

E. **Boleichthys fusiformis** Girard.

This fish was taken mainly in the inland lakes, and in some, like the Portage Lakes near Akron, it was the most abundant darter. A few specimens were taken in Lake Erie near Put-in-Bay, but none were taken from the streams of the state.

TABLE 9.

Food of *Boleicthys fusiformis.*

Length in mm.	10-15	15-20	20-25	25-30	30-35	35-40	40-50
No examined	1	24	11	9	9	3	5
Articles of diet: Copepoda	40.	12.83	16.55	2.22	4.44	5.03	.4
Cladocera	60	22.58	27.36	7.22	8.88	1.66	1.
Ostracoda		9.54	27.27	16.11	7.22		.2
Midge larvae		21.58	17.45	26.70	46.22	10.	30.4
Amphipods		27.25	10.19	13.88	17.33	41.66	11.6
May fly larvae		5.		22.22	4.05		22.
Dragon fly larvae				5.55		8.33	
Corixa nymphs				1.66	3.55		6.
Snails							16.
Isopods						31.66	
Fish remains					1.11		
Round worms					3.33		10.
Insect eggs					1.66		.4
Filamentous algae		.2		1.11	33		2.
Sand and silt		1.02	1.18	3.33	1.88	1.66	

An examination of the accompanying table shows that *Boleichthys* is a typical darter as far as its food habits go. Beginning with a diet of pure entomostraca they turn to larger food as they grow larger. Amphipods, midge larvæ and other larger insect larvæ begin to appear next in the diet while at the same time the entomostraca become less important in the food.

The diet also becomes more complex with the increase in size of the fish. In all these respects *Boleichthys* resembles *Percina caprodes*. It is remarkable that a fish feeding upon the bottom and in the midst of so much organic debris should take so little debris with its food. In sharp contrast to *Cottogaster copelandi*, which also feeds upon the bottom but takes large quantities of debris and algæ, *Boleichthys* like a true but miniature game fish selects only moving objects for food.

Summary of Food Habits in Boleichthys fusiformis.

1. Entomostraca are the chief food of the smaller specimens but this gradually gives place to larger objects as the fish grows older. 2. The diet becomes more complex with the increase in age of the fish. 3. Amphipods, midge larvæ and other insect larvæ become the important articles of food in the older specimens.

F. **Etheostoma flabellare** Rafinesque

The food habits of this little game fish present some very distinctive features. There are only traces of entomostracan food taken in the smallest specimen. When only 13 mm. in length its food consists entirely of may fly larvæ and the larvæ of midges. The size of the food animals is surprising. Frequently the entire stomach contents was found to consist of a single larva tightly wadded in the stomach. The larva was sometimes nearly as long as the fish. The size of the food increased with the size of the fish when amphipods, beetle larvæ, caddis fly larvæ and corixas were taken. Specimens from the swift streams of the state and those from Lake Erie agreed closely in their food habits but there was a total absence of amphipods in the food of stream specimens.

TABLE 10.
Food of *Etheostoma flabellare* from Lake Erie.

Length in mm.	13	14	15	16	17	18	19	20	21	22	23	24	25	26	35	36	37	40	52
No. examined	2	4	3	4	1	8	5	8	5	4	6	2	3	1	2	2	2	4	2
Articles of diet: Midgelarvae and pupae	3.		3.33	1.2		5.	17.4	5.2	.6	1.2					5.				
Amphipods					60.		10.		14.	2.5	16.6						60.	27.5	
May fly larvae	97.	100.	66.6	98.8	40.	95.	72.6	94.8	85.4	96.3	83.4	100.	100.	100.	95.	100.	40.	38.	25.
Beetle larvae																		33.8	75.
Flat worms			+															.7	

TABLE 11.

Food of *Etheostoma flabellare* from streams.

Length in mm.	10–20	20–30	30–40	40–50	50–60
No examined	5	13	5	1	1
Articles of diet:					
Copepoda	2.5				
Cladocera	1.				
Midge larvae	49.	60.7	32.	100.	
May fly larvae	47.5	39.3	48.		100.
Caddis fly larvae			8.		
Corixa nymphs			12.		

Summary of Food Habits in Etheostoma flabellare.

1. The food in the younger stages of the fish consists of may fly larvæ and midge larvæ, the food animals being quite large and proportionate to the size of the fish. 2. The larger specimens continue to eat may fly larvæ, the larvæ of midges, the larvæ of other large insects and the adults of amphipods. 3. Amphipods do not appear in the food of the stream inhabiting fish.

G. **Etheostoma cœruleum** Storer

The rainbow darter occurs in swift streams often in company with *Etheostoma flabellare.* The food resembles that of *E. flabellare* in that may fly larvæ and midge larvæ are eaten at all stages after the fish becomes active. Entomostraca are taken in fairly large numbers in the younger specimens but they decline in importance as the fish increases in size. Snails, larger insect larvæ, a few small crayfish, midge larvæ and may fly larvæ make up the diet of the larger specimens.

TABLE 12.

Food of *Etheostoma coeruleum.*

Length in mm	15–20	20–25	25–30	30–35	35–40	40–50
No examined	2	19	15	7	8	4
Articles of diet: Copepoda	40	17.53	6.93	2.62	25	
Cladocera		.37	46			
Ostracoda		.74	8			
Midge larvae	60.	37.	33.35	35.55	25.12	56.25
May fly larvae		41.85	57.33	52.55	46.25	27.50
Large Dipteran larvae		2.				
Beetle larvae					3.75	
Caddis fly larvae					10.62	
Crayfish					12.14	
Mites						1.25
Snails		.26		9.28		15.
Sand and silt		.25	.13		1.87	

Summary of Food in Etheostoma cæruleum.

1. Entomostraca are taken to a limited extent by the younger specimens but are a negligible factor in the food of the older fish. 2. May fly larvæ and midge larvæ are the chief food in all stages over 15 mm. in length. 3. Larger insect larvæ, snails, and crayfish enter into the food of the larger specimens.

H. **Etheostoma variatum** Kirtland.

Only six specimens of this fish were taken. Three were taken in Little Darby Creek and three in Big Walnut Creek, both branches of the Scioto. One was 33 mm. in length, one 34 mm., two were 35 mm., one was 36 mm. and one 58 mm. Not enough data was secured to warrant any definite statement concerning their food habits, but many fly larvæ and midge larvæ formed the only food of four and the main food for the remaining two. One had eaten 20 per cent of sand and debris and the other had taken a few mites in addition to may fly and midge larvæ.

Summary of food in Etheostoma variatum.

1. In six specimens may fly and midge larvæ formed almost the only food.

I. **Hadropterus aspro** Cope and Jordan.

Eleven specimens of this fish were taken, ranging in length from 34 to 66 mm. They were taken from the following localities: Miami River near Sidney, Plum Creek east of Ft. Laramie, Big Walnut Creek near Columbus, Black Lick Creek near Reynoldsburg, Little Darby Creek near West Jefferson, and from Deer Creek.

May fly larvæ, midge larvæ, corixa nymphs, copepods, fish remains and silt occurred in the stomachs and were so distributed as to leave the impression that there was no prevalent food for a fish of any given length. For example, a 34 mm. specimen had eaten only midge and may fly larvæ, a 39 mm. specimen had eaten 100 per cent of copepods and a 40 mm. specimen had eaten corixa nymphs and small fish. A 66 mm. fish had eaten 60 per cent of copepods, 38 per cent of may fly larvæ and 2 per cent of silt. Corixa nymphs were eaten only by those from Deer Creek and those containing a large per cent of copepods in their stomachs all came from Big Walnut and Black Lick Creeks.

Summary of Food in Hadropterus aspro.

1. The food is quite variable, may fly larvæ, midge larvæ, copepods and corixa nymphs being the most important food animals. 2. There seems to be no change in the food habits of specimens ranging from 34 mm. to 67 mm. 3. There is some evidence that Hadropterus is a random feeder, taking within certain limits whatever chances to be present.

J. **Hadropterus phoxocephalus** Nelson.

This rather rare species was taken only twice. A 53 mm. specimen was taken from the Miami River near Sidney and a 57 mm. specimen from Black Lick Creek three miles north of Reynoldsburg. As in *H. aspro* the principal food animals were midge larvæ, may fly larvæ and copepods.

K. **Ammocrypta pellucida** Baird.

Three specimens of this fish were examined. A 36 mm. specimen from Middle Bass Island near Put-in-Bay had eaten 90 per cent of midge larvæ and a little silt. One 24 mm. specimen from the west branch of the Mahoning River had taken only midge larvæ and one from Beaver Creek near Celina had eaten a little sand and several midge larvæ.

COMPARATIVE FOOD HABITS OF DIFFERENT SPECIES.

The darters belong to the family Percidæ and so are most nearly related to the perch and the pike perch. The darters are a specialized group and so far as the food habits of the young go, there is such a variety of behavior that it is difficult to select a typical mode. The perch is a generalized fish on the other hand and it is practically certain that the darters descended from an ancestral perch-like fish. In seeking for a near relative, therefore, with which to compare the darters we naturally turn to the perch. In this fish there are three well recognized but intergrading stages of food habit depending upon age. The very young subsist almost entirely on entomostraca, turning gradually to amphipods and insect larvæ—mainly midge and may fly larvæ—while the proportion of entomostraca diminishes. Still later, in the yearling and two-year-old perch the diet becomes very complex but there is a predominance of amphipods and large insect larvæ in the food. Snails and vegetable material are also eaten in considerable quantities. These three stages in the food habits of fishes have been shown by Forbes to exist in the perch and in many other fishes, especially the Centrarchidæ which are closely related to the darters and they have been designated as infancy, youth and maturity. In examining the records of the food of the darters to select those showing a typical habit, the three periods are borne in mind and those fish are selected which most nearly conform to this type of habit.

Of the eleven species examined, *Percina caprodes* most nearly meets the specifications of generalization in its food habits. The periods of infancy and of youth are well marked and the period of maturity is marked by an omnivorous habit. It would also be expected also that a fish with a generalized food habit would find survival easy and would therefore be abundant and uniformly distributed. All these requirements are met, indeed the distribution of *Percina* was identical with that of the perch in many places.

Boleichthys may also be ranked as generalized in its food habits. Beginning with entomostraca in the 12 mm. stage, it changes rapidly to amphipods and insect larvæ, never giving up the entomostraca entirely even in the 50 mm. stage. Then it passes to maturity, where the boundary is not so well marked, but may be recognized by the greater proportion of large sized food animals such as snails, isopods, dragon fly larvæ and corixa nymphs.

Diplesion blennioides passes over the stage of infancy very quickly and begins eating the food characteristic of youth by the 20 mm. stage. There is a strong tendency to take only may fly and midge larvæ on the part of the specimens from Lake Erie, while those from the streams pass into a typical maturity in which the diet becomes more complex and large insect larvæ are taken. It must be admitted, however, that if complexity of diet is to be taken as a criterion of maturity, *Diplesion* reaches maturity by the time that it has reached the 25 mm. stage.

Boleosoma nigrum begins a mixed diet very early (15 mm.). Entomostraca and minute midge larvæ continue to appear in the food through life indicating that the habits of infancy are never entirely given up. There is a marked utilization of debris also which does not occur in any other darter except *Cottogaster copelandi*.

Cottogaster copelandi. No specimens under 28 mm. in length were examined so that it is impossible to give any data concerning the stage of infancy. The period of youth is well sustained up to the 43 mm. stage and in addition there is the development of two habits that mark this group as a specialized one. These habits are the eating of bottom debris and vegetation and the consumption of fish eggs.

Hadropterus aspro. Nothing can be offered as to the habits of infancy in this fish, but the persistence of copepods, midge larvæ and may fly larvæ up to 66 mm. specimens points to a retention of the habits of infancy and of youth in the mature stage. It resembles *Boleosoma nigrum* and *Diplesion blennioides* somewhat in this respect.

Etheostoma. This genus as represented by the three species, *flabellare cæruleum* and *variatum* is characterized in its food habits by its resemblance to the mature game fishes. Vegetation and debris are seldom taken and from the earliest stages (10 mm. in *flabellare*) they capture and eat food animals that are very large in proportion to the fish eating them. Midge larvæ, may fly larvæ, beetle larvæ and corixa nymphs are some of the animals eaten. *E. flabellare* shows the greatest degree of specialization in this direction with *E. cæruleum* resembling it somewhat. There is a tendency also to omit entomostraca from the food of infancy and to take larger insect larvæ at once. *E. cœruleum* resembles the more generalized darters in this regard, having a large proportion of copepods up to the 15 mm. stage.

The length of the fish has been taken to indicate its age throughout this discussion but it is recognized that the relationship is only relative, especially when comparing members of different species. Thus it appears that *E. flabellare* has passed into the stage of youth by the time that it has gained a length of 10 mm. but *Percina caprodes* does not pass into this stage as indicated by its food habits till it reaches a length of 25 mm. After studying *P. caprodes*, therefore, one is likely to fall into the error of considering the much smaller specimens of *E. flabellare* as correspondingly younger. Indeed, it may be an error in this paper to have stated that the stage of infancy in *Etheostoma* is poorly represented, for it is possible that specimens may be found which are less than 10 mm. in length and which eat entomostracan food.

Summary of Comparison of Food Habits.

The darters may be divided roughly into three classes based upon the character of the food at the different periods in their lives. First: a group with generalized food habits such as those found in the perch and the sunfishes. In this class three periods are to be recognized in the life of an individual; infancy, when the food consists of entomostraca and minute midge larvæ, youth, in which may fly larvæ, small midge larvæ and small amphipods form the food, and maturity during which period the food is varied and is likely to contain a large proportion of large insect larvæ, large amphipods and snails. Second: one in which the period of youth is shortened or omitted and the adults subsist to a considerable extent upon vegetation and debris. Third: a group of miniature game fishes which begin at a very early stage to hunt for large may fly larvæ, midges and other active larvæ. The period of infancy is curtailed so much as to seem entirely absent or is merged with youth. The habit of taking large food animals continues to the adult stages and the habit is accompanied by an unwillingness to take either debris or vegetation.

To the first group belong *Percina caprodes* and *Boleichthys fusiformis*. To the second belong *Cottogaster copelandi* and *Boleosoma nigrum*, while *Etheostoma variatum*, *E. cœruleum* and *E. flabellare* comprise the third. *Diplesion blennioides*, *Hadropterus aspro* and *H. phoxocephalus* are related to both groups one and three and *Ammocrypta pellucida* resembles group three.

FACTORS GOVERNING FOOD CHANGES.

(*a*) *Age and Size of Fish.*

It is obvious that the smaller fish must be limited in their selection of food to such a size as it is physically possible for them to capture, while the larger ones have a greater possibility of choice. Since the size of the fish is dependent on its age, the age must enter into this principle. Records were kept of the size of the food animals taken by *Percina caprodes*, *Etheostoma cœruleum*, *E. flabellare* and *Boleichthys fusiformis* and this record compared with that of the length of the fish. A close degree of similarity was found between the size of the food animals and the size of the fish, which was quite independent of the character of the food.

(*b*) *Seasonal Position of Food Animals.*

Whether the body of water in question is a stream, a small lake or a large lake such as Lake Erie, there is a season cycle in the fauna and the flora. Phyto-plankton develops which furnishes the food for the minute crustaceans and their larvæ and for the larval forms of some insects. Submerged and floating vegetation develops which furnishes food and a retreat for insects, crustaceans and young fish all of which are important in the food relations of the darters. With the warming of the waters winter eggs of various forms hatch and the young forms produced are also important as food animals. Even eggs of insects and of fishes furnish food at certain seasons. Like all other fishes the darters are dependent for the amount and variety of their food upon the seasons in which they develop.

(*c*) *Special Structures.*

Forbes has pointed out that those fishes that retain the habit of feeding upon minute organism in their adult stages are equipped for the purpose with fine gill strainers. Some of the darters feed upon entomostraca to some extent in the adult stage but there are none that may be classed as feeding exclusively upon very small objects. An examination of the gill strainers in the different species listed here failed to show any marked differences.

The position of a terminal mouth, especially if the lower jaw is projecting, also seems to be correlated definitely with the habit of taking large and active food. *Etheostoma flabellare* is the most specialized in the development of a projecting lower jaw and it has developed the habit of taking large, active food animals more than any other. *Etheostoma cœruleum* is somewhat less specialized in both its food habits and the development of a terminal mouth but it resembles *E. flabellare.* *Boleichthys fusiformis* was taken in a situation where vegetation and debris were most abundant, but a very small trace of either appears on the food. It is a remarkably clean feeder for the environment and seems to have developed nothing of the grubbing habit, although it is bottom feeder.

(*d*) *Special Habits.*

All of the darters are considered to be very agile fish, but even among the members of an active group there are some that are more active than others. The difference in the ability of the fish to overtake and seize food animals would be reflected in the food. Of the list given here *Etheostoma flabellare* is the most active and the large, active food animals that appear in the diet are not taken by any other darter.

The habit of feeding upon the bottom seems to be well established in the adults of most species but there is a difference even here. Some of the fish have developed a habit of grubbing upon the bottom so that a large amount of debris appears incidentally in the food. *Boleosoma nigrum* is one of this sort. Others may live in the midst of debris and select only live, active food. *Boleichthys fusiformis* illustrates this type.

Percina caprodes in its very early stages is a surface feeder like the younger stages of the perch and black bass but as it matures it becomes a bottom feeder. Others like *Etheostoma flabellare* and *Boleichthys fusiformis* seem to be bottom feeders from the time that they hatch. This difference in habits has its effect upon the food; the diet of the young *P. caprodes* consists of copepods and cladocera while *E. flabellare* and *B. fusiformis* take, in addition to copepods and cladocera, midge and may fly larvæ and ostracods.

(*e*) *Different Habitats.*

Some of the darters are very limited in their habitats. Although a few seem to occur almost anywhere that a fish might be expected to live. *Cottogaster copelandi*, for example, was taken only in Lake Erie; *Etheostoma cœruleum* was confined entirely to swift streams, but *Etheostoma flabellare, Diplesion blennioides, Ammocrypta pellucida, Percina caprodes* and *Boleosoma nigrum* were found in both Lake Erie and the streams of the state. *P. caprodes* and *B. nigrum* may be expected in almost any body of water except in isolated pools. It is obvious that the small animal life of a swift stream and of a lake choked with vegetation must differ and fishes confined to such habitats must also differ in their food habits. Such a difference is much less than might be expected, however.

Percina caprodes, Etheostoma flabellare and *Diplesion blennioides* occurring both in Lake Erie and in the streams of the state afford data for a comparative study of the food of the same species of fish in different habitats. Amphipods form an important item of food in the lake specimens of both *E. flabellare* and *P. caprodes*, but they do not occur in the food of stream dwelling forms. Midge larvæ and may fly larvæ are found in the food of both stream and lake specimens, but species differences are common. The same is true of the molluscan diet. Planorbis and Physa were the snails utilized as food in lake specimens but the flat gastropod, Ancylus, was the only snail found in the food of stream darters. Some specimens of *P. caprodes* were found which had taken as many as thirty of the latter snail.

FOOD AND DISTRIBUTION.

With the exception of *Boleichthys fusiformis*, all the darters mentioned in this paper seem to be rather generally distributed. *Boleichthys* has been taken only in the northern part of the state, but there is no peculiarity in the food which could account for this geographical limitation. Locally, however, the character of the food probably determines the range and distribution of the fish. Taking the food that they do and having the food habits which are characteristic of them, it would not be expected that *Etheostoma flabellare* and *E. cæruleum* would be found in stagnant water. Nor on the other hand, would it be expected that there would be found species like *Cottogaster copelandi* in swift brooks, when it is given to eating large proportions of vegetation and debris.

If any fish were able to adapt itself to several kinds of habitats, it should be one of generalized habits, for specialized habits whether food, reproductive or otherwise, limit the scope of any animal. The wide range, uniform distribution, and common occurrence of *Percina caprodes* are no doubt partly due to the fact that the animal is unspecialized and is able to become adapted to various habitats. The change in food habits as Percina becomes a stream dweller, when it was formerly a lake fish, may be cited as an instance of such an adaptation in food behavior.

SUMMARY.

1. The food of the Ohio darters varies with the fishes. In the most typical cases the young feed exclusively upon entomostraca, turning to midge larvæ and other small insect larvæ later, and when mature feeding upon a varied diet in which ephemerid larvæ and other large insect larvæ predominate. The fish with the most typical food habits is *Percina caprodes*.

2. Some of the darters vary from this habit of eating insect larvæ in the younger stages by apparently omitting the entomostraca from the first stage. These fish are characterized, even in the adult, by the large size of the food animals taken. *Etheostoma flabellare* is the most specialized in this regard with *Etheostoma cæruleum* resembling it.

3. Other darters after passing through a rather typical first and second stage eat a large percentage of vegetable material and organic debris in their older stages. *Cottogaster copelandi* is the most typical one of this group.

4. Amphipods occur regularly in the food of most lake specimens but are entirely lacking in those from streams.

5. When members of a species are taken from both streams and lakes there is a marked difference in the food animals although there is usually a close adherence to the typical food habit.

6. Factors governing the food of the darters are: (a) The age and size of the fish; (b) Seasonal position of food animals; (c) Special structures in the fishes (terminal or ventral mouth, etc.); (d) Special types of behavior of the fish; (e) Different habitats.

7. Different food habits are not sufficient to account for the distribution of the Ohio darters except locally.

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NOTES ON THE DODDER GALL WEEVIL, SMICRONYX SCULPTICOLLIS CASEY

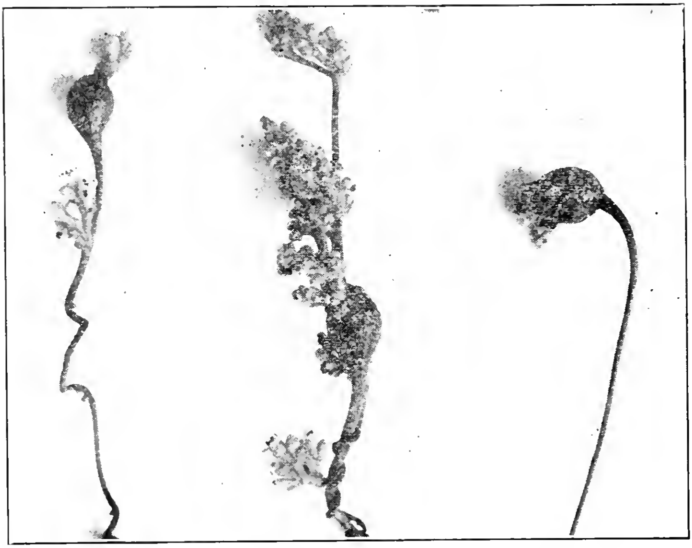
HARRY B. WEISS AND ERDMAN WEST
New Jersey Department of Agriculture

Numerous galls were noted on dodder, *Cuscuta cephalanthi* Eng., at Monmouth Junction, N. J., during the first part of August. Upon collecting and cutting some of the swellings open, several beetles were obtained. At this time most of the galls contained larvæ and a few pupæ. The adult was identified as *Smicronyx sculpticollis* which identification was confirmed later by Mr. C. W. Leng. During the last of August quite a few of the galls contain adults nearly ready to emerge; in fact a few beetles will have emerged by this time. However, most of them leave the galls during the first half of September and later in central New Jersey, emergence taking place through a circular opening in the side.

Each gall is single celled and consists usually of a broadly fusiform or subglobular enlargement of the peduncle of the flower cluster, which normally is comparatively thick and fleshy. (Text figure 1.) Many galls were noted which appeared to be enlarged nodes. The completed galls were for the most part subglobular in shape and about four to six millimeters in diameter, while the younger ones were broadly fusiform as a rule. In a few cases the galls were quite irregular due to having been pressed out of shape by contact with the host of the dodder or to having been constricted by the dodder itself. The galls are light yellow to orange in color, a few being somewhat greenish.

LARVA. Length about 2.25 mm. Form subcylindrical, slightly curved, tapering slightly at both ends; sparsely hairy, hairs short; color light yellow, head light brown. Head small, subcircular, slightly depressed; collum absent; epicranial halves separated dorsally by a very faint median suture; front triangular; gula indistinct, membranous; ventral mouth parts fleshy; clypeus and labrum distinct, former transverse; antennæ minute almost obsolete; ocelli absent. Mandibles of biting type, broad across base, bifid at tip with a comparatively minute tooth below the two terminal ones. Maxilla fused with labium to near apex; lacinia simple, fringed with chitinous hairs on inner surface; galea absent; maxillary palpi two-jointed, labium fleshy with mentum and submentum fused, indistinct; labial palpi one jointed. True legs absent indicated by ambulatory tubercles. Thoracic and abdominal segments each with three dorsal plicæ. Cerci absent. Anal segment wart-like.

PUPA. Length about 2.25 mm. Light yellow, oval. Head and beak bearing several minute hairs. Prothorax dorsally bears a row of about twelve distantly placed chitinous hairs on anterior, lateral, and part of posterior edges; a pair of similar hairs on middle dorsal portion of prothorax; mesothorax with a pair of shorter chitinous hairs arising near posterior lateral edge; metathorax with a similar pair arising from middle lateral portion; each abdominal segment with a transverse dorsal row of distantly placed chitinous hairs; abdomen terminated by a pair of outwardly directed chitinous spines. All hairs arising from tuberculate bases.



Galls on the Dodder, *Cuscuta cephalanthi*

ADULT. *Smicronyx sculpticollis.* This was described by Casey from Indiana, Virginia and Texas. (Ann. N. Y. Ac. Sci. VI, p. 403, 1892). According to Blatchley and Leng (Rhynch N. E. Amer., p. 218) it is known to occur in New Jersey, Long Island, District of Columbia, Illinois, Kansas and Iowa. In Smith's Insects of New Jersey it is recorded from Clementon, August 9, and Sea Isle City, June 11. Blatchley and Leng state that this species is distinguished from its nearest allies by the small densely punctured thorax, narrow hair-like scales and almost wholly dull red elytra. Many of our specimens had black elytra except for a pale, reddish-brown, broad stripe extending from humerus to apex. The extent of the black or reddish-brown areas appears to vary slightly. It was noted that immature beetles were almost wholly reddish-brown, the black first appearing along the suture and later spreading laterally.

In Rhynchophora of North Eastern America under the species Smicronyx tychoides Lec., (p. 218) there appears the statement, "said to have been bred from galls on dodder, *Cuscuta gronovii*, by Zabriskie" and it is quite probable that this record refers to *sculpticollis* especially as "specimens named *tychoides* in the Leng collection from Long Island proved to be *sculpticollis*.

OHIO ACADEMY OF SCIENCE

ANNUAL MEETING

At a meeting of the Executive Committee, held on December 17th, it was decided to hold the next Annual Meeting of the Ohio Academy in Columbus, April 14th and 15th, 1922. The preliminary notice of the meeting will be mailed by the Secretary about the first of March.

Edward L. Rice,
Secretary of the Academy.

THE OHIO JOURNAL OF SCIENCE

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A SYNOPSIS OF THE GENUS STENOCRANUS, AND A NEW SPECIES OF MYSIDIA. (HOMOPTERA).

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State Plant Board of Mississippi

The genus *Stenocranus* was founded by Fieber in 1866 and since that time three species have been placed in it from Europe, *minutus* Fab., *fuscovittatus* Stal. and *longipennis* Curt., *Maculipes*, described from South America by Berg in 1879 from a single female, has never been recognized since. In 1914, Crawford in his "Contribution towards a Monograph of the Delphacidæ" described *angustus* from British Honduras, *rostrifrons* from Cuba, and *similis* from Alabama.

Stenocranus crœcus of Van Duzee is now wrongly placed in the genus *Kelisia* and *saccharivorus* of Westwood does not seem to belong here. At present there are eight species described from the New World and the following paper brings the total up to twelve.

As the original descriptions are widely scattered, for the most part in publications not readily accessible to the ordinary worker, it seems advisable at this time to review the genus, describing the new species and giving comparative outline drawings of heads and the male genitalia, all drawn to the same scale.

All of the species, so far as known, with the exception of *similis*, occur on coarse grasses, rushes and sedges in swampy and boggy places. *Similis*, however, occurs abundantly on the bamboo-cane, *Arundinaria* tecta.

Nearly all of the members of this genus are of a pale straw to brown color with a more or less distinct dorsal whitish median vitta that runs from the vertex, over the thorax and scutellum, and is continued on the elytra by the pale commisural nervures. The legs are usually lineated with fuscous.

The genus may be briefly characterized as follows: Body slender, rather long. Head together with the eyes narrower than pronotum; vertex more or less elongate, slightly converging to apex, somewhat rectangular, and produced from one-fourth to two-thirds its length beyond the eyes; frons long and narrow, slightly broader at apex than at base, tricarinate. Eyes more or less compressed, not deeply emarginate below. Antennæ rather short, first segment shorter than the second, the latter usually somewhat tuberculate. Thorax slender; lateral carinæ usually attaining the hind margin; scutellum tricarinate. Calcar tectiform, the margins usually rather close together with pubescence between. Female ovipositor sheath subcylindrical, often broadened or foliaceous and appressed to genital segment. Probable type of genus is *Stenocranus minutus* Fab.

From the present study it seems that the final criterion for specific determination in most of the species is an accurate figure of the male genitalia. This character is constant within the species and quite distinctive.

Figures I and II are the work of Wm. P. Osborn of Syracuse University.

KEY TO THE SPECIES OF STENOCRANUS.

1. Calcar usually large and foliaceous; vertex much produced beyond eyes....2
   Calcar not unusually large, seldom foliaceous; vertex shorter..............3
2. Frons pale, with a brown band below antennæ; first antennal segment only a little shorter than the second....................*palaetus* V. Duzee
   Frons without band; first antennal segment about as long as the second, *longicornis* Dozier
3. Female ovipositor sheath broadened conspicuously, not styliform or cylindrical..4
   Female ovipositor sheath more or less cylindrical, at least on apical two-thirds..8
4. Frons narrowed above, sides subparallel from ocelli to apex; vertex not produced more than one-third its length beyond eyes....................5
   Frons broadest at apex, sides uniformly diverging from base; female ovipositor sheath less foliaceous, narrower.............................7
5. Vertex not more than one and a half times as long as broad posteriorly; frons usually less than three times as long as broad......................6
   Vertex at least twice as long as broad; frons narrow, fully three times as long as broad, or more, black between carinæ............*angustus* Crawford
6. Female ovipositor sheath broadly elliptical, broadest midway; frons usually black between carinæ..........................*dorsalis* Fitch
   Female ovipositor sheath slightly narrower, broadened apically, not as closely appressed as in *dorsalis*.............................*vittatus* Stal
   Female ovipositor sheath broadest apically, pyriform; frons pale brown between carinæ; vertex and frons relatively shorter.........*felti* V. Duzee
7. Vertex produced considerably more than half its length before eyes, beak-shaped, fully four times as long as broad..........*rostrifrons* Crawford

8\. Male pygofer rather long and narrow, with ventral margin deeply and acutely angled emarginate; genital styles long and slender. . ***breviceps*** Dozier
Male pygofer comparatively small; genital styles large at base, narrowing only slightly beyond middle and enlarging distad, with inner tip pointed, *croceus* Van D.
Male pygofer medium sized, excavated into a large median spur and two lateral ones; anal tube with a long sharp median process on ventral margin . . . . *hinei* Dozier
Male pygofer large, ventral margin roundingly emarginate; anal tube long, produced ventrad into two much longer processes than in *dorsalis;* genital styles large, constricted one-third of length from base, distal third converging to acute apex . . . . *similis* Crawford

Stenocranus dorsalis Fitch.
(1851 Homop. N. Y. St. Cab., p. 46).

Many species bear a close resemblance to *dorsalis* and are often confused with it on superficial examination. The genitalia are quite distinct and characteristic in both sexes and afford the most sure means of specific determination.

Head narrower than pronotum, strongly carinate. Vertex long and narrow, about one and a half times as long as broad posteriorly, produced about one-third its length beyond the eyes. Front long and narrow, narrowed above, slightly but quite abruptly broadened to ocelli, thence parallel to apex; median carina sometimes forked a little below apex of head. Antennæ rather short, the second segment three times as long as the first. Pronotum moderately long, scarcely as long as the vertex, lateral carinæ arcuate, attaining the hind margin. Scutellum about twice as long as pronotum, tricarinate. Elytra long and narrow. Calcar large, half as long as the basal tarsus, somewhat pubescent.

General color light yellowish-brown to brown, the dorsum usually with a long whitish vitta that extends from the vertex to the tip of scutellum and is continued by the whitish margin of the clavus when the elytra are closed; this vitta is variable in distinctness and width. Front and clypeus with the intra-carinal spaces black. Antennæ pale. Elytra usually subhyaline, light brown, occasionally darker, with a more or less prominent brown macula along membrane slightly behind middle and often extending somewhat on to corium. Sexes similar in coloration. Legs pale; femora and tibiæ striped with fuscous.

Female ovipositor sheath greatly broadened, foliaceous, closely appressed to and entirely covering genital segment, elevated on margins, and often covered with floccous secretion.

Male pygofer large; anal tube with two long, acute processes on ventral margin; genital styles large at base, abruptly narrowed midway, thence deeply emarginate, sinuate, acute at tip.

Length of body, 2.50–3 mm.; length to tip of elytra, 4.50–5 mm.

Redescribed from a large series from many states. This is our most common and most widely distributed species of the genus, being found abundantly on sedges over most of the United States and Canada.

Stenocranus vittatus Stal.
(1862 Berliner Ent. Zeits., VI, p. 315).

This species, described from Carolina and Pennsylvania by Stal as *Delphax vittatus*, has not since been recognized. I have on hand a single female, collected at Gainesville, Fla., by the writer in 1917, a series of four females and two males collected by C. J. Drake at the same locality, May 5, 1918, one male from Hattiesburg, Miss., Aug. 10, 1921, and a series of two males and a female taken by the writer sweeping grass and sedges in a swamp near Meridian, Miss., Aug. 14, 1921, that I place as this species.

Although very strongly resembling *dorsalis* and probably long confused with that species, it is quite distinct and is easily distinguished by its smaller size and the shape of the male genital styles.

Identical in structure and wing venation with *dorsalis*. General color darker brown with the median white dorsal vitta very distinct itself and made very prominent by the deeper fuscous of the pronotum, scutellum and elytra. Intra-carinal spaces of front and clypeus dark fuscous. Antennæ pale. Elytra of a much darker fuscous on corium than in *dorsalis* and there is a dark brown macula towards apex, with the apical nervures prominently infuscated. Tergum of female marked with fuscous and red, darker in male. Femora and tibiæ lineated with fuscous.

Female pygofer pale fuscous, broad, foliaceous, greatly resembling that of *dorsalis*, but broadest apically and not so closely appressed to the genital segment.

Male pygofer fuscous, comparatively smaller than in *dorsalis;* genital styles broad at base, abruptly narrowed almost midway, thence deeply emarginate, and then roundingly drawn out to acute tip; anal tube with two acute lateral processes on ventral margin.

Length of body, 2.25 mm.; length to tip of elytra, 3.50–4.25 mm.

I include here the original description in Latin and a translation of the same:

"*Delphax vittata* Stal.—griseo-straminea, supra infuscata; fronte clypeoque fuscis, pallido-carinatis; vitta verticis thoracis scutellique nec non commissura pure stramineis; tegminibus fuscescentibus apicem versus obscurioribus, maculis duabus parvis marginis commissuralis prope apicem, parteque lata costali subvinaceo-hyalinis, venis transversis apicalibus hujus partis fuscis et fusco-marginatis; capite modice prominente. ♀. Long. cum tegm. 5 millim.

"Patria: Carolina meridionalis et Pennsylvania. (Mus. Holm.)."

Delphax vittata Stal.—gray-stramineous, infuscated above; frons and clypeus fuscous, palely carinated; the vitta on vertex, thorax, and scutellum bright stramineous and also the commisure, stramineous. Tegmina fuscous, rather obscure towards the apex, with two small spots on the commisural margin near apex, and a wide part of the costa somewhat wine-colored-hyaline, transverse apical veins of this part fuscous and margined with fuscous. Head moderately prominent. Female. Length with tegm. 5 mm.

Country: South Carolina and Pennsylvania. (Mus. Holm.).

Stenocranus felti Van D.

(1910 Trans. Am. Ent. Soc., xxxvi, p. 88).

Closely allied to *dorsalis*, differing principally in having the apex of the vertex broader and more rounded, the front proportionately broader and shorter, and the pygofer of female is much broader apically and almost pyriform.

Head decidedly narrower than the pronotum. Vertex produced about one-third its length beyond the eyes, carinæ distinct. Front long and narrow, sides subparallel, narrowed towards base tricarinate. Antennæ with second segment about three times as long as the first; seta short. Pronotum as long as the vertex, tricarinate, the lateral carinæ attaining the hind margin. Scutellum short, about one and a half times as long as the pronotum, tricarinate. Elytra comparatively very short and broad and are held in a more or less roof-shaped position. Calcar slender.

General color a soiled yellowish-testaceous with the carinæ a little paler and the dorsum marked with a whitish vitta from near the front of the vertex to the tip of the scutellum, which is continued by the pale commisural nervure of the closed elytra. Front with the intra-carinal spaces pale brown or almost concolorous. Basal segment of antennæ with a black mark inferiorly, a similar mark on the cheek below the ocellus, and the antennal socket has a distinct black marginal spot anteriorly. Venter in the male black with the segments edged with orange. Elytra in the female pale yellowish hyaline with the nervures a little darker, sometimes becoming almost black on the clavus and inner margin of corium; the second apical nervure and the apex of the others deep black. In the male the nervures are almost entirely blackish fuscous, and the black of the second apical nervure is spread over the adjoining areole. Legs lineated with fuscous.

Female ovipositor sheath broadest apically, pyriform, fuscous, foliaceous, closely appressed to and covering the genital segment; anal style large and fuscous.

Male pygofer light brown in color, base fuscous, large, with ventral margin roundingly excavated; genital styles reddish-brown, large at base and pointed on either side about middle, then roundingly and abruptly emarginate, narrowed and drawn out to an acute tip; anal tube with a sharp, reddish-brown tooth each side.

Length of body 3 mm.; length to tip of elytra, 4–5 mm.

Redescribed from a series of males and females taken at Cranberry Lake, N. Y., July 5, 1917, by C. J. Drake, and a female from Orono, Maine, taken May 31, 1914, by H. M. Parshley. Also known from New Hampshire. This species occurs in low wooded swamps and bogs.

Stenocranus similis Crawford.

(1914 Proc. U. S. Natl. Mus., xlvi, p. 591, two figs.)

Female of similar color and about the same size of *dorsalis* which it very closely resembles superficially. The usual white vitta is seldom or indistinctly present.

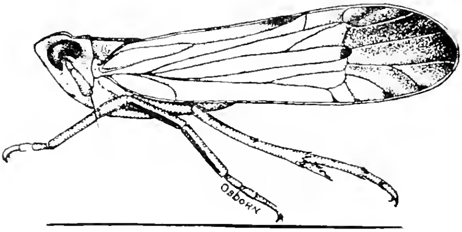


FIG. 1. Female of *Stenocranus similis*

Head narrower than pronotum. Vertex long, wider at base and narrowed towards the apex, produced about one-third its length beyond the eyes, carinæ distinct. Frons long and narrow, tricarinate. Second antennal segment three times as long as first; seta fuscous, twice the length of the second segment. Pronotum slightly shorter than vertex, tricarinate, the lateral carinæ well-rounded and attaining the hind margin. Scutellum over one and a half times as long as pronotum, tricarinate. Calcar large, but rather slender.

General color light yellowish-brown with the usual white dorsal vitta generally missing or very indistinct. Intra-carinal spaces of front and apex of vertex light to dark fuscous. Antennæ pale. Eyes pale yellowish-brown to fuscous. Elytra subhyaline, usually light yellowish-brown, a fuscous spot on inner margin at junction of claval and commisural veins; radio-medial cross-vein and apical ones at their tips, infuscated. In the male the tip of the elytron, beginning with the cross-veins, is deeply infuscated, forming a large round spot. Abdomen pale in female, more infuscated in male. Legs lineated with fuscous.

Female genital segment longer and narrower than in *dorsalis;* ovipositor sheath not foliaceous, cylindrical and extending almost to tip of abdomen.

Male pygofer large; anal tube long, produced ventrad into two much longer processes than in *dorsalis;* anal style short; genital styles large, constricted one-third of length from base, distal third converging to acute apex.

Length of body, female, 3 mm.; male, 2.75 mm.; length to tip of elytra, female, 5 mm.; male 4.25 mm.

Redescribed from a large series of males and females collected in Mississippi by the writer at Aberdeen, June 26, 1921, Columbus, June 23, 1921; Tupelo, July 2, 1921; Fulton, July 4, 1921; and Rokeena, July 20, 1921; and two females taken at Clemson College, S. C., by G. G. Aineslie. These were all swept in abundance from cane-brake and the only definitely known host plant is the bamboo-cane, *Arundinaria tecta.*

Stenocranus palaetus Van D.
(1897 Bul. Buf. Soc. Nat. Sci., v, p. 232).

Form and size of *dorsalis.* Distinguished by its long vertex and large, foliaceous tibial spur and banded frons.

Head decidedly narrower than pronotum. Vertex extended half its length beyond the eyes, carinæ prominent except median one, which is faint. First antennal segment a little shorter than the second. Pronotum slightly shorter than the vertex, strongly tricarinate, the lateral carinæ attaining the hind margin. Scutellum one and a half times as long as pronotum, tricarinate, the lateral carinæ rather indistinct. Calcar unusually large and foliaceous.

Color is fulvous yellow above, paler beneath. Frontal fovæ interruptedly black over the apex of the head from the base of the antennæ to the middle of the vertex; front crossed by a brown band below the antennæ, and another crossing the base of the clypeus and extending over the anterior coxæ and pleural pieces; apex of front and its median carina interruptedly pale. Antennæ somewhat fuscous. Eyes black. Elytra subhyaline, nervures yellowish, the commisural white with a brown line before the apex of the clavus; inner sector of the corium and the apical nervures, except the base of the two outer, fuscous; a smoky cloud covers the anastomosis at the base of the middle apical areole and spreads feebly over the inner area of the membrane. Tergum brownish. Legs pale, femora lineated and the tibiæ banded with fuscous.

Female genitalia typical. Male pygofer trilobate, middle lobe with a somewhat semicircular median notch, each side of which is extended tooth-like; lateral lobes, genital styles, and anal style dark fuscous; anal tube without ventral processes.

Male slightly smaller than female, with slightly shorter vertex; otherwise similar in appearance.

Length of body, male, 2.75 mm.; female, 3.50 mm.; length to tip of elytra, male, 4 mm.; female, 4.9 mm.

Redescribed from two males and two females taken at Gainesville, Fla., May 5, 1918, by C. J. Drake; one female from Perkinston, Miss., taken June 25, 1921, by F. H. Benjamin; and a female from Ocean Springs, Miss., June 28, 1921.

Nothing is known of its food plant or habitat.

Stenocranus longicornis sp. nov.

Very closely allied to *S. palætus* both in general appearance, large tibial spur, and genitalia but differentiated at once by the very long antennæ and distinct male genitalia.

Vertex proportionately long, produced beyond the eyes slightly more than a third its length, carinæ distinct. Front very long, narrowest between the eyes, enlarging below. Antennæ long, the first segment about as long as the second. Tibial spur unusually large. Pronotum shorter than the vertex, distinctly tricarinate with the lateral carinæ attaining the hind margin. Scutellum about twice the length of pronotum, tricarinate.

General color dark brown. Vertex, pronotum and scutellum dark piceous, whitish along median carina. Front and clypeus dark with edges of carinæ paler. Second antennal segment light brown, first segment paler. Eyes brown. Elytra subhyaline, nervures prominent, fuscous. Tergum fuscous with genitalia paler. Legs pale, faintly and indistinctly lineated with fuscous.

Male pygofer trilobate, lateral lobes curved around behind, ventral margin of median lobe roundingly emarginate with a large hairy lateral tooth each side; pygofer pale brown with the drawn out base darker; genital styles rather short and stout, dark; armature of diaphragm produced in two long teeth; aedeagus apparently forked.

Length of body 2.75 mm.; length to tip of elytra, 4 mm.

Described from a single male, taken at light trap at Ocean Springs, Miss., Aug. 3, 1921, by the author. I do not hesitate to describe this species from a single specimen as it is quite distinct.

Type in author's collection.

Stenocranus breviceps sp. nov.

In general appearance of female quite similar to *dorsalis* and *angustatus* but easily distinguished from these and the other members of the genus by its short and very broad vertex, the comparatively long elytra, well rounded at the tips and distinct male genitalia.

Head slightly narrower than prothorax, vertex short, somewhat rectangular in shape, produced about one-fourth of its length beyond eyes, strongly carinate. Frons one-third as broad as long, narrowed above, distinctly carinate. Antennæ rather short, second segment three times as long as first. Pronotum long, proportionately broad; carinæ on account of their whitish color are indistinct, the lateral ones not attaining the hind margin. Elytra long, narrow, enlarging towards the apex, well rounded at tips. Legs slender; calcar typical, slender, pubescence slight.

General color light yellowish-brown to brown. Dorsum with more or less distinct whitish vitta, continued by the pale commisural nervure of the closed elytra. Carinæ of vertex, front and clypeus whitish with intra-carinal spaces black. Distal end of basal segment of antennæ with black mark, a similar mark on the cheek below the ocellus. Pronotum for the most part of a pale whitish color, a fuscous band bordering each side of the median white vitta, and fuscous markings at sides of pro- and mesonotum. Scutellum whitish. In the female the elytra are of a uniform pale yellowish to brown hyaline, with nervures whitish. In the male the inner half of the elytra below the commisural nervure is more deeply enfumed; the tip of the elytron beginning with the transverse veins is deeply infuscated, forming an almost round apical dark area within which the nervures are fuscous.

Female ovipositor sheath longer and narrower than in *dorsalis*, pale in color, the ovipositor fuscous.

Male pygofer rather long and narrow, with ventral margin deeply and acutely angled emarginate; genital styles long and slender, stouter at base.

Length of body, female, 3 mm.; male, 2.5 mm.; length to tip of elytra, female, 5 mm.; male 4.25 mm.

Described from a series of ten females and five males taken by the writer sweeping sedges and marsh vegetation at Moss Point ferry across Pascagoula River, Pascagoula, Miss., Aug. 8, 1921.

Holotype and allotype in author's collection. Paratypes deposited in U. S. National Museum and collections of the State Plant Board of Mississippi. Prof. Herbert Osborn and Z. P. Metcalf.

Stenocranus croceus Van D.

(1902 Bul. Buf. Soc. Nat. Sci., v, p. 233).

Closely allied to *dorsalis* but very much smaller, of a general yellowish-orange appearance, and the front is shorter and wider.

Vertex short, produced beyond the eyes about one-third its length, carinæ distinct. Front long, rather broad, narrowing gradually to base and slightly rounded to clypeus, tricarinate. First antennal segment one-third as long as second. Pronotum as long as vertex, tricarinate, carinæ attaining hind margin. Scutellum about twice as long as pronotum, tricarinate.

General color pale yellowish-orange, although slightly more sordid in some specimens. Vertex, pronotum and scutellum yellowish-orange or sordid yellow, with whitish band along median carina. Front and clypeus yellowish-orange with pale area along each side of median carina. Antennæ pale. Eyes brown. Elytra subhyaline, nervures, especially the commissural one, pale. Tergum yellowish-orange. Legs pale, without markings; tarsal claws piceous; calcar typical, large and distinctly dentate.

Female ovipositor sheath narrower than in *dorsalis*, and not foliaceous; not closely appressed to nor entirely covering the genital segment; pale orange-yellow with the ovipositor itself darker.

Male genitalia in single specimen on hand obscure. Pygofer fairly large, ventral margin roundingly emarginate; genital styles quite different from those of *dorsalis*, large at base, narrowing only slightly beyond middle and enlarging distad, with the inner tip pointed.

Length of body, 2.50–3 mm.; length to tip of elytra, 3.75–4.75 mm.

Redescribed from a single mutilated male and a female from Devil's Lake, N. D., two females from Brookings, S. D., one female from Delphos, Kan., and two females from Springer, N. Mex., all collected during July, 1909, by Prof. Herbert Osborn, and a large series of both sexes from Portland, Maine, August 13, 1913, H. Osborn.

Stenocranus hinei, sp. nov.

Resembles *breviceps* superficially but is smaller, the legs unmarked and the male genitalia quite distinct.

Head slightly narrower than pronotum. Vertex short, produced beyond the eyes about one-fourth its length, carinæ rather indistinct, especially the median one, which is almost obsolete. Front long and narrow, narrowing to base, one-third as broad as long, tricarinate. Antennæ with second segment three times as long as the first; seta fuscous, three times as long as the second segment. Pronotum not quite as long as the vertex, tricarinate, with the lateral carinæ almost attaining the hind margin. Scutellum tricarinate. Elytra long and narrow. Legs slender; calcar typical, long and slender.

General color pale yellowish-brown with whitish median vitta, this vitta accentuated by the fuscous stripes bordering it on the pronotum and scutellum. Frontal carinæ whitish with the spaces between dark fuscous. Genæ dark fuscous next to the lateral carinæ of front, whitish beyond to antennæ. Antennæ pale, unmarked. Eyes light brown. Elytra in both sexes pale soiled yellow to hyaline brown with the commisural nervure whitish; nervures pale, becoming brown in ante-apical cells; radio-medial cross-nervure and anteapical nervures at tips, infuscated. Legs pale, unmarked.

Female ovipositor sheath long, somewhat foliaceous, extending beyond tip of abdomen, sides subparallel.

Male pygofer medium in size, excavated into a large median spur and two longer lateral ones; anal tube with a long, sharp median process on ventral margin; genital styles rather long, larger at base, narrowing in middle, much enlarged, retorsed, and cut off distad, very pale in color; aedeagus of dark fuscous chitin, composed of three parts, the ventral one rather stout, sharp, and barbed, the middle one thorn-like, very long and sharp, the upper one short and stout with a pair of curved hooks at tip.

Length to tip of elytron, male, 4 mm.; female, 4.75 mm.

The male is similar to the female in coloration and markings, but is smaller.

Described from a series of nineteen males and fourteen females, taken sweeping at swamp edge, Los Amates, Guatemala, Jan. 17, 1905, by Prof. J. S. Hine, after whom I name the species.

Holotype and allotype in collection of Prof. Herbert Osborn as well as those paratypes not otherwise designated. Paratypes in U. S. National Museum and in the collections of Z. P. Metcalf and the author.

Stenocranus angustus Crawford.

(1914 Proc. U. S. Natl. Mus., xlvi, p. 589).

As I have not seen the original type specimen I am including here the original description.

"Length of body, 3.1 mm.; width of vertex, 0.20; width of frons, 0.22; antennæ, I, 0.05; II, 0.22. General color brown or dark brown, dorsum with conspicuous white vitta; frons black between carinæ; femora striped black; elytra mostly dark brown except outer anteapical and costal cell and small part of membrane light.

Vertex about as long as in *dorsalis*, projecting about one-third its length before eyes, about twice as long as broad; frons one-third as broad as long, slightly narrowed at ocelli.

Thorax slender; prothorax not much broader than head; scutellum long. Calcar slender. Elytra long and very slender.

Male genitalia somewhat similar to *dorsalis;* styles more slender and delicate, very acute and slender distad.

Described from one male, taken at Belize, British Honduras, by J. D. Johnson. This species is similar in many respects to the northern *S. dorsalis*.

Type-specimen.—In collection of Pomona College, Cal."

Stenocranus rostrifrons Crawford.

(1914 Proc. U. S. Natl. Mus., xlvi, p. 591, two figs.)

"Length of body, 3.6 mm.; width of vertex, 0.20; length to apex of head, 0.72; width of frons, 0.21; antennæ I, 0.07; II, 0.21. General color yellowish orange; frons with a slender black stripe near apex of above; antennæ lineated narrowly with black beneath or in front.

Head long, narrower than prothorax, strongly carinate between eyes, produced almost two-thirds of its length beyond eyes, curved down somewhat and resembling very closely a bird's beak, acute at apex; vertex very elongate, narrow, about four times as long as broad, narrowed anteriorly; median carina almost wanting; frons elongate, broadest below, not strongly carinate; eyes rather small; ocelli conspicuous. Antennæ not as long as width of head between antennal sockets, II about three times as long as I.

Thorax slender, long, not strongly carinate; pronotum about two and a half times as long as scutellum, broadly emarginate behind. Calcar typical, pubescence slight. Elytra long, strongly attenuate at base, more rhomboidal apically than in congenors, maculate on membrane veins; venation somewhat different from that of congenors.

Female ovipositor sheath somewhat broadened, about midway between foliaceous and cylindrical.

Described from one female from Habana, Cuba (Baker). Type-specimen.—In collection of Pomona College, Cal."

Stenocranus maculipes Berg.

(1879 Hemipt. Argentina, p. 223).

This species was placed in the genus *Delphax* by Berg but without question should be assigned to *Stenocranus*, at least until again recognized. I am including here a translation from the original Latin description:

"Female: Fuscous, here and there variegated with testaceous, elytra and legs testaceous, the former with fuscous veins, and infuscated at interior margin, the latter obscurely spotted and banded with fuscous; hind part of head narrower than pronotum, produced beyond the eyes; vertex longer by half than its basal width, somewhat narrowed upwards, margins strongly elevated, median carina lacking, the two lateral carinæ meeting at an acute point; frons and clypeus tricarinate, the former scarcely curving on both sides before the middle, then very slightly widened towards apex, banded with white in front of the middle and at apex; clypeus white at base; first antennal segment somewhat compressed, second somewhat longer and more slender, the latter strongly tuberculate, above and below a little dilated; pro- and mesonotum obscurely fuscous, tricarinate, the former widened behind, carinæ distinct, rather pale, the latter with lateral carinæ somewhat obsolete, median carina extended all the way to apex of scutellum; elytra much longer than abdomen, subhyaline, all veins and the interior margin partly infuscate; wings hyaline; dorsum and venter of abdomen fuscous; greater part of femora blackish-brown, tibiæ with two blackish bands, hind ones bispinose in front of the middle; tarsi light yellowish, partly fuscous. Length of body, 4½ mm.; elytra, 4½; width of meson, 1 mm.

"Country: Province of Buenos Ayres."

Of this species I received from Sr. Ed. Lynch Arribalzaga, one individual that was collected in Rio Lujan during the month of February, 1879.

A comparative study of the male genitalia of the members of this genus show that *dorsalis*, *vittatus*, *felti*, *angustus*, *similis*, and *croceus* are very closely related to each other. *Palætus* and *longicornis* on the other hand form an entirely distinct type of development with the pygofer more or less trilobate. *Breviceps* shows a third type in which the ventral margin of the pygofer is deeply and angularly emarginate. *Hinei* is the sole representative of a fourth type having the pygofer formed of a median and two lateral large teeth and with a single median anal process. *Rostrifrons* is known from a single female and therefore no comparison can be made of the male genitalia.

The relation of these species to one another as shown in a study of the genitalia is borne out by the external structure.

The Genus Mysidia Westwood.

Many of the members of this genus closely resemble certain small whitish Geometrid moths. They run very swiftly on the upper surface of leaves or when caught in a net, with their wings partially raised. The genus is tropical, at least nine species occurring in Central America and nothing is known of their life-history. Heretofore no species has been known from North America.

For the most part members of this genus are of a white more or less opaque color; the head is narrow and compressed; the antennæ have the first joint short, the second large and swollen, more or less pointed or truncate, the third consisting of a fine seta; the tegmina are very long and rather narrow, much larger than the wings, both vitreous, with the veins very light in color with occasional more or less obscure markings. One of the best characteristics of the genus is the large number of long, narrow, and very regular apical areas.

Mysidia mississippiensis, sp. nov.

Technical description.—Head, antennæ, pronotum and scutellum yellowish, covered more or less with whitish powder, abdomen with greenish tinge; abdominal plates meet in a median ridge; head very narrow, compressed, distinctly produced before the eyes and plainly longer than the pronotum; eyes dark brown; pronotum narrow with sides flaring-like. Tegmina and wings translucent, of a milky-white color, venation distinctly but not strongly marked; tegmina long and rather narrow, with very light fuscous areas especially along the transverse veins and a distinct fuscous patch near middle of the posterior margin of tegmina. Legs very slender, testaceous.

Length of body, male, 2.50 mm.; female, 3 mm.; wing expansion, male, 15 mm.; female, 17 mm.

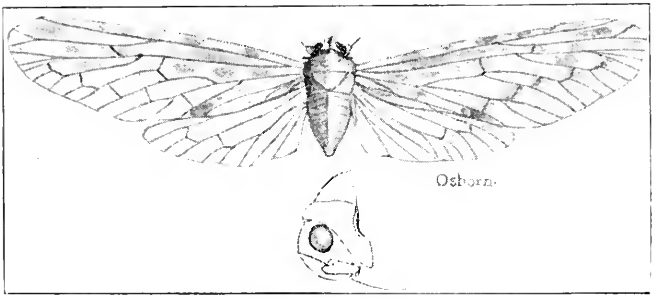


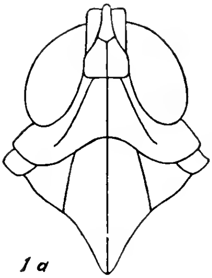
FIG. 2. *Mysidia mississippiensis*

Described from a single female taken by the writer sweeping *Arundinaria* and grass in Oktibbee Swamp near Meridian, Miss., Aug. 14, 1921, and a series of two females and a male taken in a swamp near Leland, Miss., Sept. 15, 1921, by C. J. Drake.

Type in the author's collection. Paratypes deposited in collections of Prof. Herbert Osborn, Z. P. Metcalf, and the State Plant Board of Mississippi.

A Synopsis of the Genus Stenocranus
H. L. Dozier

PLATE I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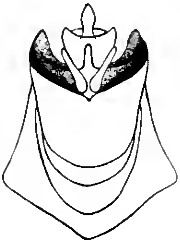
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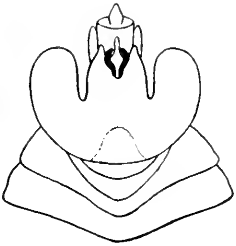
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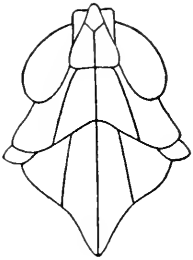
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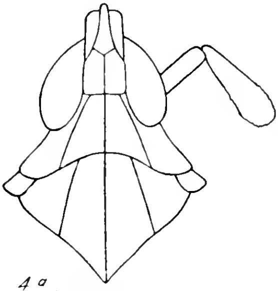
croceus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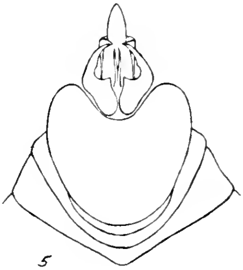
longicornis


4 b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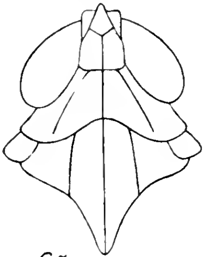
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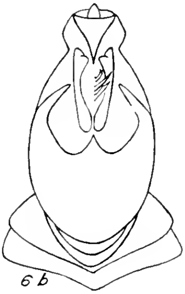
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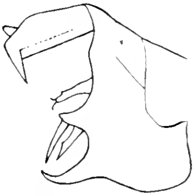
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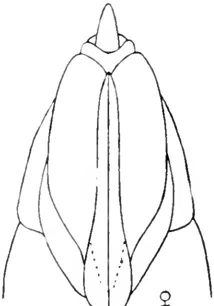
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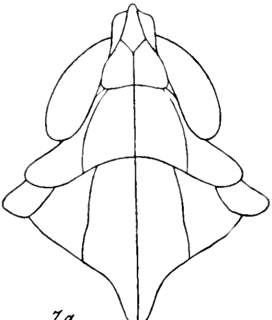
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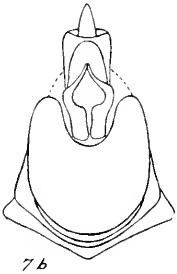
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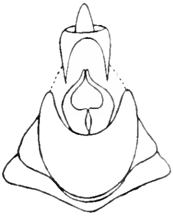
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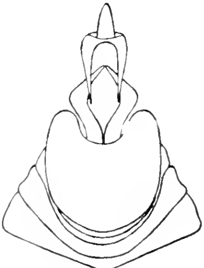
9 similis

H. L. Dozier, del.

THE HOMOLOGIES OF THE TRACHEAL BRANCHES IN THE RESPIRATORY SYSTEM OF INSECTS

CLARENCE HAMILTON KENNEDY
Department of Zoology and Entomology, Ohio State University

The following study of the tracheation of the Zygoptera was undertaken to determine the homologies of the tracheal branches that supply parts of the genitalia of the second and third segments of the male. This full investigation will eventually appear in one of the government publications but the study brought to light points of so much greater importance that a discussion of these was given at the Toronto Meetings of which this article is the outline.

Grassi* has shown the probability that the insect tracheal system was originally a series of disconnected segmental systems which later fused into a connected whole.

Chapman† has homologized the main thoracic tracheæ which form the main air supply of the wings in the various orders of insects, and has shown us that the tracheal system can be homologized but so far no attempt has been made to refer these back to the more generalized (?) plan found in the tracheation of the abdominal segments. In the majority of the general morphological works on insects the tracheal system is described as being composed of certain longitudinal trunks with various accessory parts in the way of spiracles, air sacs, cross-connections, etc. This is true, but these are not descriptions which take into consideration the origin and homologies of the individual parts of the tracheal system.

The Zygopterous naiad, among the nymphs, of all winged insects, appears to have the abdominal segments least modified from a probable primitive condition. Its abdomen is clyindrical, therefore no parts are displaced or lost by depression. Its gills are at the apex of the abdomen, therefore their position does not modify any but the caudal parts of the system. The abdomen is elongate so that each segment can be studied individually.

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* Atti dell' Accad. Groenia d. Sci. Nat. Catania (3) T. XIX. 1885.

† In "Wings of Insects," Comstock, pp. 27–51.

The nymph of *Lestes*, which furnished the material for this study, is so abundant and so transparent that little dissection was needed.

In this article the writer will outline the homologies of the principal thoracic tracheal branches as referred back to the simpler system of an individual abdominal segment. The terms used are descriptive as far as possible and were worked out with the help of Dr. Chapman with the hope that we had terms that would be useful in future tracheal studies.

If the reader will refer to the plate he will see in Fig. 1 the simplest tracheal unit in abdominal segment 2. It is repeated in segments 3–7. Segments 1 and 8–10 have more or less modified versions of this same unit. In the thorax the tracheal branches are yet more highly modified. The diagram Fig. 3, shows what the writer considers as the hypothetical primitive unit from which the present system with its longitudinal trunks has been developed.

The studies of the primitive tracheal systems in *Peripatus* and in the embryology of the insectean tracheal system show that the spiracles develop first as pits. From the bases of these pits the tracheal branches develop. Our unit starts then with (1) the *spiracle*, sp., extending into the body wall, (2) is the *spiracular* pit, spp. From the bottom of this there develops dorsad a short stout branch, (3) the *spiracular trunk*, spt. This trunk forks and sends a branch, (4) the *anterior dorsal connective*, adc. to the muscles of the anterior end of the segment, and a branch (5) the *posterior dorsal connective*, pdc. to the posterior muscles of the dorsum of the segment. Each of these has a branched tip supplying its group of muscles, (6) (7) the *tip* of the *anterior dorsal connective*, tadc, and the *tip* of the *posterior dorsal connective*, tpdc. These tips become landmarks later in the study.

The *spiracular pit* sends out three other branches, (8) *the anterior spiracular connective*, asc, which connects forward to the leg trachea and which gives off a small branch to the body wall, (9) *the posterior latero-tergal trachea*, plt. Opposite to this (8) is given off a larger trachea, (10) *the leg trachea*, lt, which runs caudad and ventrad. It gives off first, (11) *the anterior latero-tergal trachea*, alt, to the body wall, then (12) *the pleural trachea*, pt, to the pleural fold. Ventrad the spiracular pit gives off a slender branch direct to the ganglion of the segment (13) the *ganglionic trachea*, gt. This has a tip which runs along the sternum caudad from the ganglion, (14) *the sternal trachea*, st.

As this hypothetical unit is derived from the tracheal system as it appears in the less modified abdominal segments these terms are directly applicable to the parts in Fig. 1. In this figure it will be seen that the anterior and posterior dorsal connective have united as they alternate along the dorsum into a large dorsal trunk. In *Lestes* it is especially large as it functions with its mate of the opposite side, as a swim bladder, while along it at regular intervals are the *tips* of the *anterior and posterior* dorsal connectives.

In the front end of the abdomen the ganglions of segments 1 and 2 have each moved cephalad one segment. In each case the *ganglionic trachea* has followed its ganglion cephalad. The ganglion of segment 1 fuses with that of the metathorax but the elements of the tracheal supply are still recognizable. See Fig. 2, which is a ventral view of the thorax.

In each segment the *anterior spiracular connective* has fused with the *leg trachea* next ahead so that in the abdomen there is a delicate but complete lateral trunk. In the thorax a pair of ventral or sternal trunks appear by the fusion of the *sternal tracheæ* with each succeeding *ganglionic trachea*. This fusion is not completed in the abdomen. See Fig. 2.

In the thorax but two spiracles persist, the mesothoracic and the metathoracic. Of the prothoracic spiracle, some of the tracheal branches are present which would be expected with it but the spiracle itself has left no recognizable trace. The tracheal system of the metathorax is least modified. Here the spiracular trunk is still fully developed. In the mesothorax the spiracle has moved dorsad until the *spiracular trunk*, st, has been obliterated. It is also entirely lost for the prothorax.

The modification of the thorax due to the development of the wings has profoundly changed the proportions of the other thoracic branches also. In a later paper the writer will trace this change from the first instar where it is very similar to the abdominal tracheal system through its development to the extreme modification shown in Fig. 1 which is a tenth instar naiad.

The wings start as simple pleural folds no wise different from those of the abdomen. By the fourth instar those of the thorax have moved dorsad and those of the mesothorax and metathorax have begun to take on the place and shape of wing pads. The simple *pleural trachea*, pt, tracheates them in the beginning and follows them as they pass from the lateral to their final dorsal position. The *pleural trachea* is the anterior or costal wing supply and is the original wing supply as this devlopment shows. As the wing folds (later, pads) pass dorsad they pass the *tips* of an *anterior* and a *posterior dorsal connectives* in each segment and take on connections with these. Also the anal apex of each wing trachea (*pleural trachea*) connects also with the *anterior latero-tergal trachea* of the succeeding segment. Thus each wing in *Lestes* has four tracheal connections.

Several puzzling shifts and specializations have taken place. In segment 1 the leg branch is lost and the *anterior spiracular connective* has shifted from the spiracle down onto the *ganglionic trachea*. This has occurred also in the second and third thoracic segments so that the *posterior latero-tergal trachea* in each case has shifted to arise from near the spiracle.

In the metathorax the *metathoracic tip* of *the posterior dorsal connective* has shifted down onto the vertical *spiracular trunk*. This conclusion is arrived at by elimination of the other *tips*. This solution homologizes the tracheation of the hind wing with the tracheation of the front wing.

In the thorax the *ganglionic trachea* have shifted down onto the *leg trachea* in each segment, and in each segment a second or *accessory ganglionic trachea*, agt, has appeared.

The shortening of the *spiracular trunk* in the mesothorax has pulled the *leg trachea* of the prothorax out of shape and has greatly shortened the *anterior spiracular connective* of the mesothoracic spiracle so that the lateral trunk becomes a second dorsal trunk in the insect's neck.

This work in tracheation is very much confused by malformations and adventitious branches. Frequently there are two or even three *anterior* or *posterior latero-tergal tracheæ*, sometimes two *pleural tracheæ*, etc. One has to examine enough specimens that these abnormalities are recognized as such and no longer confuse. This readiness of the tracheal system to develop new branches has been one of the things which has made homologization of the branches seem a hopeless task.

The tracheation of the internal organs seems to be largely fortuitous except for two large trachea that run from the *metathoracic spiracular trunks* to the region of the gut just back of the gizzard and two others that run from the *spiracular trunks* in abdominal segment 8 to the region of the intestine just back of the malpighian tubules. The tracheation of the head is very definite but so far has not been homologized with the parts of the system in the thorax and abdomen unless the tracheæ of the labium can be homologized with *leg tracheæ.*

This study supports the theory that the wings are developed from pleural folds as this feature can be positively homologized from the larval pleural fold stage to the adult winged stage.

The only other order the writer has examined is the Plecoptera. Here the tracheal system is greatly distorted by the thoracic gills and the depressed body. A pair of neural trunks are formed in the abdomen by the fusion of the *sternal tracheæ.* A lateral abdominal trunk is well developed which is probably homologous with the lateral trunk of the Zygoptera though this may be found to be homologous with the dorsal trunk of the Zygoptera. The thoracic trachea are less changed.

The writer believes that this reference of the tracheal branches back to those in a generalized abdominal segment will give a solution to the homolgies of the tracheal systems in the various orders of insects. He hopes soon to carry the study farther.

EXPLANATION OF PLATE.

Fig. 1. Lateral view of *Lestes* naiad, male, showing the homologies of the somatic tracheal branches.

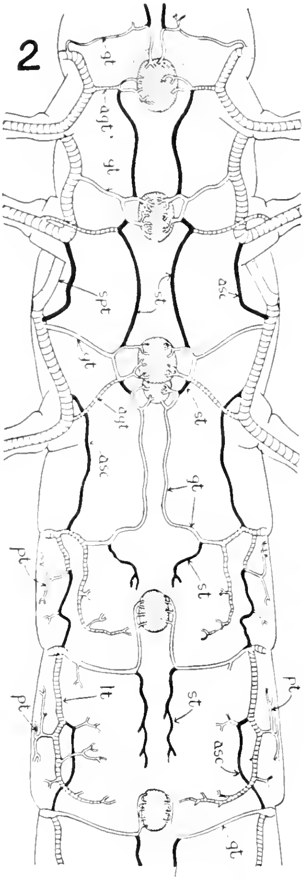
Fig. 2. Ventral view of *Lestes* naiad.

Fig. 3. Hypothetical, primitive segmental tracheal organs. By the fusion of a series of such the *Lestes* trachial system may have been developed.

LIST OF ABBREVIATIONS USED IN THE ILLUSTRATIONS.

sp.—spiracle.
spp.—spiracular pit.
spt.—spiracular trunk.
st.—sternal trachea.
dt.—dorsal trunk.
latt.—lateral trunk.
vt.—ventral trunk.
lt.—leg trachea.
pt.—pleural trachea.
gt.—ganglionic trachea.
agt.—accessory ganglionic trachea.
asc.—anterior spiracular connective.
adc.—anterior dorsal connective.
pdc.—posterior dorsal connective.
alt.—anterior latero-tergal trachea.
plt.—posterior latero-tergal trachea.
tadc.—tip of anterior dorsal connective.
tpdc.—tip of posterior dorsal connective.

2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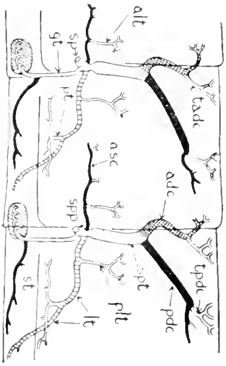
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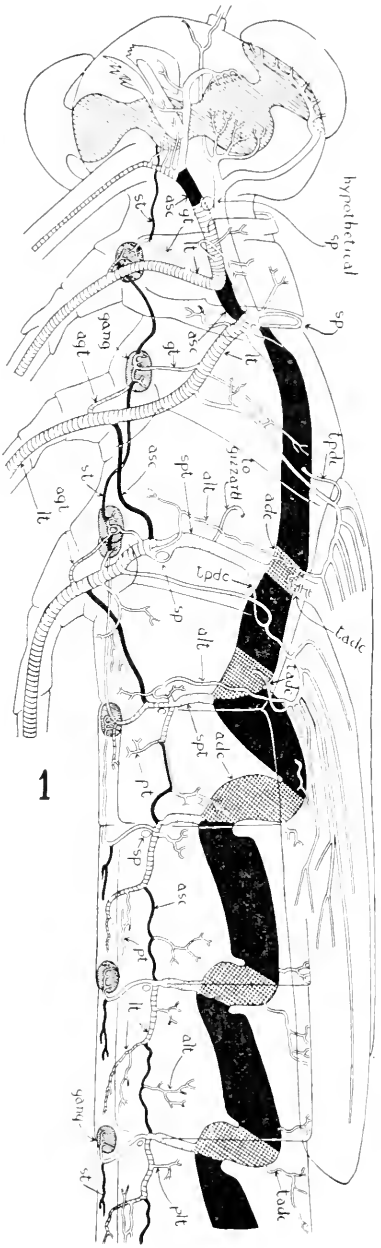
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ADDITIONS TO THE CATALOG OF OHIO VASCULAR PLANTS FOR 1921.*

JOHN H. SCHAFFNER
Department of Botany, Ohio State University

During the past year a number of additions have been made to the Ohio flora and some important extensions of ranges have been detected. Below is given a list of the more important additions, with some corrections of species names.

54. *Equisetum fluviatile* L. Swamp Horsetail. Cedar Swamp, south of Urbana, Champaign Co. John H. Schaffner.

71. *Pinus echinata* Mill. Shortleaf Yellow Pine. Jackson Twp., Jackson Co., Wilkesville and Vinton Twps., Vinton Co. "This pine is generally distributed over N. E. Jackson County, and is the dominant pine with scrub and pitch pines. Its occurrence, however, in Vinton County is rather limited and restricted, occurring always on the ridges." F .W. Dean.

72. *Thuja occidentalis* L. Arborvitae. On east bank of Brush creek, Bratton Twp., Adams Co. Katie M. Roads.

236. *Carex platyphylla* Car. Broadleaf Sedge. Hillsboro, Highland Co. Katie M. Roads.

384. *Sporobolus vaginaeflorus* (Torr.) Wood. Sheathed Rush-grass. Hillsboro, Highland Co. Katie M. Roads.

414. Change name to *Torresia odorata* (L.) Hitchc. instead of *Savastana odorata* (L.) Scrib. Add: Specimens from Blanchester, Clinton Co. "Wet meadows." E. Lucy Braun.

545. *Juncus torreyi* Cov. Torrey's Rush. Hillsboro, Highland Co. Katie M. Roads.

552.1. *Juncoides bulbosum* (Wood) Small. Bulb-bearing Wood-rush. Blanchester, Clinton Co. "Wet meadows." E. Lucy Braun.

567. *Fissipes acaulis* (Ait.) Small. Moccasin-flower. Ironton, Lawrence Co. Lillian E. Humphrey.

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* Papers from the Department of Botany, Ohio State University. No. 132.

662. *Sarracenia purpurea* L. Pitcher-plant. Cranberry Island, Buckeye Lake, Licking Co. Spreading abundantly from a single plant set out several years ago by Miss Freda Detmers. Hundreds of vigorous plants now cover a considerable area of the open Sphagnum bog. John H. Schaffner.

663. *Drosera rotundifolia* L. Roundleaf Sundew. Cedar Swamp, southern part of Clarke Co. Mrs. Bayard Taylor.

683. *Koniga maritima* (L.) R. Br. Sweet Alyssum. "Persistent and an escape from cultivation." Hillsboro, Highland Co. Katie M. Roads.

706. *Sophia pinnata.* (Walt.) Howell. Pinnate Tanzy-mustard. Gravel slide, Huffman Dam, Greene Co. Also in Clark Co. A. E. Waller.

714. *Conringia orientalis* (L.) Dum. Hare's-ear-mustard. Hillsboro, Highland Co. Katie M. Roads.

739. *Dentaria diphylla* Mx. Two-leaf Toothwort. Near Hillsboro, Highland Co. Katie M. Roads.

744. *Sinapis arvensis* L. Corn Mustard. "In waste places and gardens." Hillsboro, Highland Co. Katie M. Roads.

746. *Brassica juncea* (L.) Cosson. Indian Mustard. Hillsboro, Highland Co. Katie M. Roads.

805.1. *Tithymalus falcatus* (L.) Kl. & Garke. Native of Europe. Along railroad between Fairmount and Westwood, near Cincinnati, Hamilton Co. Louis H. Desjardins.

925. *Dianthus armeria* L. Deptford Pink. "In a pasture lot." Hillsboro, Highland Co. Katie M. Roads.

1009. *Potentilla recta* L. Upright Cinquefoil. Roadside near Bainbridge, Ross Co. A. E. Waller.

1286. *Alnus incana* (L.) Willd. Hoary Alder. Cedar Swamp, south of Urbana, Champaign Co. John H. Schaffner.

1323.1. *Opuntia tortispina* Engelm. Twisted-spine Prickly-pear. In large patches in gravel soil in railroad cut, Terrace Park, Cincinnati, Hamilton Co. From the west. E. Lucy Braun.

1420. *Phlox pilosa* L. Downy Phlox. "In pine woods." Ironton, Lawrence Co. Lillian E. Humphrey.

1434. *Convolvulus japonicus* Thunb. Japanese Bindweed. Escaped along a road near Brooks, Clark Co. John H. Schaffner.

1465. *Gentiana crinita* Froel. Fringed Gentian. "In a swamp" near Canton, Stark Co. Mary King.

1471. *Frasera carolinensis* Walt. American Columbo. Blendon and Pleasant Twps., Franklin Co. John H. Schaffner.

1526.1. *Paulownia tomentosa* (Thunb.) Baill. Paulownia. Escaped in Ironton, Lawrence Co. Lillian E. Humphrey.

1529. *Conobea multifida* (Mx.) Benth. Conobea. Hillsboro, Highland Co. Katie M. Roads.

The following changes of names should be made in the family Scrophulariaceae, to agree with the treatment of the Ohio species by Mary A. Taylor in "The Figworts of Ohio," Ohio Jour. Sci. 21:217-239, 1921. The sequence of genera and species should also follow the arrangement given there.

1530. *Gratiola neglecta* Torr. instead of Gratiola virginiana L.

1531. *Gratiola virginiana* L., instead of Gratiola sphaerocarpa Ell.

1547. *Veronicastrum virginicum* (L.) Farw. instead of Leptandra virginica (L.) Nutt.

1551. *Dasistoma macrophylla* (Nutt.) Raf. instead of Afzelia macrophylla (Nutt.) Ktz.

1552. *Aureolaria pedicularia* (L.) Raf. instead of Dasystoma pedicularia (L.) Benth.

1553. *Aureolaria virginica* (L.) Pennell, instead of Dasystoma flava (L.) Wood.

1554. *Aureolaria laevigata* (Raf.) Raf., instead of Dasystoma laevigata Raf.

1555. *Aureolaria flava* (L.) Farw. instead of Dasystoma virginica (L.) Britt.

1686. *Salvia lyrata* L. Lyreleaf Sage. Paint Twp., Highland Co. Katie M. Roads.

1695a. *Plantago aristata* nuttallii (Rapn.) Morris. A peculiar but probably merely a depauperate form of P. aristata. Gallipolis, Gallia Co. R. H. Martin.

1761. *Galium pilosum* Ait. Hairy Bedstraw. Paint Twp., Highland Co. Katie M. Roads.

1777. *Viburnum dentatum* L. Toothed Arrow-wood. "Wet meadows and undrained flats." Martinsville, Clinton Co. E. Lucy Braun.

1778. *Viburnum scabrellum* (T. & G.) Chapm. Roughleaf Arrow-wood. Union Twp., Highland Co. Katie M. Roads.

1786.1. *Triostium aurantiacum* Bickn. Scarlet-fruited Horse-gentian. Toboso, Licking Co. E. N. Transeau.

1794. *Lonicera japonica* Thunb. Japanese Honeysuckle. "Collected on the bank of a small pond." Hillsboro, Highland Co. Katie M. Roads.

1873. *Bidens aristosa* (Mx.) Britt. Western Tickseed. Bratten Twp., Adams Co. Katie M. Roads.

1948. *Aster junceus* Ait. Rush Aster. "Wet meadows." Midland, Clinton Co. E. Lucy Braun.

1952. *Aster multiflorus* Ait. Dense-flowered Aster. Omit Gallia Co. from distribution.

1964.1. *Leptilon divaricatum* (Mx.) Raf. Low Horseweed. "Dry sandy soil, roadside." From the west. Winton Place, Cincinnati, Hamilton Co. E. Lucy Braun.

2005.1. *Artemisia ludoviciana* Nutt. Western Mugwort. Established along the interurban track near Brooks, Clark Co. From the west. John H. Schaffner.

2030.1. *Centaurea solstitialis* L. Barnaby's Star-thistle. Archbold, Fulton Co. In alfalfa field introduced with alfalfa seed. John S. Nofzinger. Also at Lima, Allen Co. L. S. Van Natta.

NOTES ON THE FOOD HABITS OF YOUNG OF COTTUS ICTALOPS (Millers Thumb.)

C. L. TURNER
Zoological Labaratory, Beloit College

While the writer was engaged in collecting the fry of the Perch and of the Darters in the vicinity of Put-in-Bay, preparatory to making a study of their food habits a locality was found in which the young of *Cottus ictalops* were fairly abundant.

Around the shores of Buckeye Island there is an abundance of short, thick vegetation, shaded by willows and protected and held together by willow roots. This margin is constantly awash due to the exposed position of the island. The young of Cottus ictalops and of the Fan Tailed Darter (*Etheostoma flabellare*) were found hiding in the vegetation and under the rocks in the vicinity. It was not possible to take the fish in a seine because they were so well protected but a small collection was secured by persistently dragging the vegetation with a flat ended dip net.

About a hundred specimens were taken ranging in size from 12 to 22 millimeters and the stomach contents of thirty-five were examined. The food articles have been arranged in a tabular form showing the proportion of each kind of food eaten by each size of fish.

Although ten different articles occur in the food some of them are almost negligible in quantity and even the youngest fish seem to prefer large, active Amphipods or insect larvæ. In some cases a single insect larva, two-thirds as long as the fish filled the stomach.

The young of most fish subsist on Entomostraca during the younger stages, turning later to specialized and larger foods. In a fish of generalized feeding habits the time during which it takes Entomostraca is known as the period of infancy, a later period when midge larvæ and other minute insect larvæ are used is known as the period of youth, while the stage in which the usual food of the adult is taken is designated as the period of maturity. The period of infancy seems to be entirely omitted or to be passed over in specimens of less than 12 millimeters in length. In this regard it resembles *Etheostoma flabellare,* which unlike most of the other darters captures large, active food while still very small and if it takes Entomostraca at all it does so only in negligible quantities.

The adult Millers Thumb is reported to be a voracious feeder and very destructive to other fish. It is interesting that the young resemble the adult in their ability and their willingness to capture large food animals which are proportionately large even in 12 millimeter specimens. It is well adapted to feeding upon large objects by its large terminal mouth.

Table illustrating the food of young of Cottus ictalops.

Length in mm.	12	13	14	15	16	17	18	19	20	21	22
No. examined	1	1	1	2	3	5	5	5	5	4	3
Articles of diet:											
Midge larvae	100.		100.	2.5	33.33+	22.6	20.	22.5	28.75		1.66+
May fly larvae		60.			51.66+	43.8	54.	25.	32.5	75.	81.66+
Amphipods				47.5	15.	27.4	18.	52.5	12.5	12.5	
Fish remains		40.					6.		20.	12.5	
Bottom debris									5.		
Beetle larvae				48.5							16.66+
Round worms						1.2					
Filamentous algae						1.					
Fish eggs				1.5		4.	2.				
Insect eggs									1.25		

Figures represent the percentage of the volume of the stomach contents.

CONCRETIONS IN LAKE DEPOSITS AT ELYRIA, OHIO

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Excavations near the corner of Middle Avenue and Sixth Street, Elyria, made preparatory to the erection of heating plant extensions for the school buildings located there, have brought to light some calcareous sand and clay concretions in the making.

The pit is twelve or fourteen feet in depth. The section is as follows:

4. Filling, artificial, (clay, brick-bats, crockery, etc.), 2 ft.
3. Brown to yellow sands and clays................8 ft.
2. Blue and blue-gray clays......................2 ft.
1. Blue sands................................1-2 ft.

Layer number one is micaceous sand and in parts argillaceous. It gives under the weight of horses and wagon and behaves much like quicksands. It seems to be full of water, but the water is not flowing through. Layer number two is dryer and is variable in thickness, the upper surface being quite uneven. In places the layers above seem to be pushed into it. In other parts a yellow stain seems to have penetrated the blue clays from some point or line of seepage, in concentric spheres or layers. Thus the yellow above and the blue below are mutually interpenetrating and uneven. It is along this uneven contact that the concretions occur. The circulating water responsible for the concretions seems to be moving through layer three and descending to number two.

Some of the concretions are small and of indefinite boundaries and shapes, some are larger and resemble in shape lemons, cocoanuts and even vases a foot high, with a diameter of three or four inches. Most concretions have a nucleus of some sort. In many of these there seems to be a twig or branch of wood, a quarter of an inch to an inch in diameter, which reaches the whole length of the structure. In most cases, this twig retains some of its woody structure and fiber. The clay and sand surround the stem and the cementing has been done in concentric shells. Layers are thicker in the central part, which fact makes the concretion thicker in its equatorial zone. Only partial cementing has yet been effected, and acid tests indicate that the cement is calcium carbonate.

All the concretions were yellow or brown, although embedded in the blue clays. It is obvious that oxidized iron from the upper layers is penetrating the blue with the calcium carbonate and that both are being deposited, thus solidifying the clay and sand of the concretions. Yet the structure is still soft and can be easily cut with the finger nail. We have here a number of concretion shapes still in the process of making.

A few hundred yards north or down the slope lakeward from this deposit is the shore line of Lake Whittlesey, a precursor of the present Lake Erie; and some three miles south is the abandoned beach of the Maumee stage. This latter beach is known east of Elyria as Butternut Ridge, and the former is now occupied through the business section of town by Main Street. The clays and sands then are between the Maumee and Whittlesey beaches and therefore belong to the Maumee Lake stage. While Maumee Lake was held in on the north and east by ice and overflowed through the Fort Wayne, Indiana, outlet, its waves and currents built the Maumee beach around the Elyria embayment, and on its floor were laid the clays and sands found in the excavation. Hence the concretions can be correlated with the Maumee Lake stage and can be shown to be wholly post-glacial. Concretions have been completed in a time period equal to this, but those found at Elyria seem to be still in the process of growth and cementation.

PRESERVATION OF NATURAL CONDITIONS.

E. LUCY BRAUN
University of Cincinnati

The Ecological Society of America desires to publish a National and International list of areas suitable for biological study in North America and northern South America. All preserved areas in natural or semi-natural condition, such as forest preserves and bird and game sanctuaries; and all other areas in a natural state, even though they may not be preserved, should be included. It is hoped that the inclusion of tracts doomed to exploitation, but still in a natural state, will stimulate interest and lead to the selection of areas in regions where as yet there has seemed to be no interest in preservation.

Each area is to be described briefly. The description should include the following points, so far as possible:

(1) A statement as to the nature of vegetation—forest (and type), prairie, swamp, sand dune, etc.—and principal trees or other plants. If succession is well illustrated, this should be stated.
(2) The animals, including birds and fish, should be noted.
(3) The topography of the area—level, rolling, sharp, precipitous, dissected—and the altitude (highest and lowest points, or average for level areas) should be stated.
(4) If streams or lakes are present, describe briefly, as to current, depth, width, nature of bottom, purity, etc., and animal life.
(5) Locate area, and give directions for reaching it, with name of transportation company, and distance and direction from some easily located point or points. Give desirable means of reaching the area; on foot, by automobile, horseback. Name nearest post office and nearest town at which through trains stop.
(6) Give name of nearest town with hotel accommodations; or if camp outfit is desirable or necessary.
(7) Any reference to literature dealing with the areas described should be included.

(8) If the area is a preserve, state agency which owns, and controls and manages the preserve. (A preserved area is one publicly owned or owned by an incorporated institution).

The work of collecting the information about natural areas and preserves has been apportioned by states. In addition to the description of areas, information is wanted about other features of natural interest in each state.

(1) Caves: Name, location, approximate size (if known), geological formation.
(2) Location of unpolluted waters.
(3) Description of lake coast areas still in a natural condition.
(4) References to literature.

If *you* know of any preserve or natural area in Ohio (or elsewhere) which should be included, *describe it.* Do not fail to describe areas because you think it has already been done; additional data will invariably be added where descriptions are duplicated by different persons.

Do your share in helping to make that part of the "Naturalist's Guide" dealing with Ohio as complete as possible, by sending information as outlined above.

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PROGRESSION OF SEXUAL EVOLUTION IN THE PLANT KINGDOM*

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Sexuality may manifest itself in at least three different ways: First, by the property of attraction and fusion of cells; second, by the dimorphism of characters expressed through the influence of the sexual state at the time of cell differentiation; and third, by a difference in the nature of the chemical bodies produced in cells in different sexual states. In the evolution of sex there are, apparently, degrees of intensity of the sexual state and degrees of persistency of any state established for the time, whether male, female, or neutral. The main factor in the evolution of sexual dimorphism has been the shifting of the time in the ontogeny when sexual states arise from the neutral state or when one sexual state gives place to another. The time of sex determination ranges all the way from a late stage of gametogenesis in the lowest forms backward through the ontogenetic history until, as in diecious flowering plants of the extreme type, the sexual state of both the sporophyte and gametophyte is established at the time of fertilization of the egg or even before. Of course, it must be remembered that new hereditary factors are continually arising or old ones being modified, in the upward progression of evolution, which come to expression either in the presence of one sexual state or the other or in the presence of both sexual states but with different morphological values. In either case the dimorphism of secondary sexual characters becomes more pronounced or more complex.

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* Papers from the Department of Botany, The Ohio State University. No. 133.

If sexuality is a physiological state of the cells, then it becomes evident that sex reversal might take place at any time and in any cell or tissue. A neutral condition may change to a male state or to a female state, or one sexual state may give place to the other, or a sexual state may revert to a neutral state again. Such reversals not only take place naturally in hermaphroditic, bisporangiate, monecious and monosporangiate individuals, but they can be induced in various ways by artificial means in diecious sporophytes, as has been done by the writer and others in *Cannabis sativa*, *Humulus japonicus*, *Arisæma triphyllum*, and *Arisæma dracontium*.

If a distinction is to be made between different categories of sexual characters, then in order to avoid confusion of ideas and improper deductions, the terms "primary" and "secondary" need a more exact definition for application in genetics than they have received heretofore.

The proper place to draw the line is between gametes on the one hand and all other cells on the other. The ordinary dimorphic characters are produced because of the presence of a sexual state and not because of differences in heredity of the cells involved. A primary sexual character is, therefore, defined as any sexual character possessed by a gamete. A secondary sexual character is any sexual character possessed by any cell, tissue, or organ other than a gamete. Thus the wall cells and stalks of spermaries and ovaries may show secondary sexual characters comparable to those of cells farther away in the vegetative body. The main differences in primary sexual characters pertain to the size and shape of the gametes, size of or presence and absence of flagella, differences in activity, differences in food contents, and differences in color. The fundamental differences exhibited between eggs and sperms are often quite uniform throughout a class or phylum, while secondary sexual characters may be quite diverse.

The lowest plants are apparently devoid of sexual states during their entire life cycle, and the first indications of sex are entirely physiological. Passing on from this condition of a physiological state, the first appearance of a structural difference or dimorphism appears in the gametes. These differences soon reach a general, normal, dimorphic condition in the Gonidiophyta with well-differentiated eggs and sperms. So long as organisms are unicellular they cannot be described as hermaphrodites. They must be either male or female although they may be vegetative sister cells. So soon as a multicellular condition is attained hermaphroditic individuals are possible, and in the lower multicellular forms hermaphroditism is the usual condition. If a progeny of unicellular individuals coming from an ancestral cell by vegetative growth develops some as male cells and some as female, we evidently have a condition essentially like an ordinary multicellular hermaphrodite; for if the cells remained associated after division instead of splitting apart the combined units going into the sexual state at a certain stage of their life history would represent genetical conditions identical to a multicellular hermaphrodite. The further evolution from hermaphrodites is by gradual steps to unisexual, multicellular individuals. In the higher plants with an antithetic alternation of generations, the sporophyte is in the lower levels entirely neutral and homosporous, showing no sexual states; and from this condition the higher bisporangiate type with heterospory is evolved. The heterosporous sporophytes of the lowest types have bisporangiate leaves or bisporangiate floral axes. This is the general condition from which both monecious and diecious species are derived. In the monecious individual the entire floral axis is monosporangiate or the entire inflorescence, while in the extreme diecious condition the entire individual produces but one kind of spores, or in other words has but one kind of sexual expression. The highest plants, therefore, have unisexual, dimorphic gametophytes and diecious, dimorphic sporophytes.

The detailed description of these evolutionary series is given in outline below although no attempt has been made to catalog the numerous intermediate and special cases.

I. NONSEXUAL STAGE.

1. The organization of the protoplast is apparently such that the origin of sexual states or phases is impossible. This may be true both morphologically and chemically. No sexual state is shown at any stage of the life cycle although there is considerable evolution and morphological differentiation displayed by the highest species of this type of plants.

Apparent examples: Merismopedia, Micrococcus, Ankistrodesmus, Rivularia.

II. LOWER SEXUAL SERIES, WITH REDUCTION OF THE CHROMOSOMES EITHER IN THE ZYGOTE, OR AT THE END OF THE SEXUAL GENERATION JUST BEFORE GAMETOGENESIS.

2. The lowest sexual condition in which sexuality manifests itself by the development of a passing state of attraction between two morphologically similar mature cells or isogametes. In the most primitive cases there is no apparent morphological or physiological differentiation outside of the property of attraction.

Examples: Diatoms, Desmids, Sphærella, Botrydium, Cladophora, Ulothrix, Ectocarpus.

Note: We may assume that there is a chemical or physical, or perhaps it would be better to say a physiological difference corresponding to female and male states.

3. Development of a difference in size and sometimes color of the gametes which in typical cases are ciliated, free-swimming cells.

Examples: Pandorina, Bryopsis, Codium, Spirogyra sp.

Note: Spirogyra shows a considerable degree of heterogamy in its highest species.

4. The stage of sexual evolution in which the gametes are typically differentiated as male and female with a decided dimorphism, the sperm cell being ciliated and small with little cytoplasm and food supply and actively motile after being discharged from the gametangium, the egg cell being nonciliated and comparatively large with abundant cytoplasm and food supply and also discharged from the gametangium although nonmotile.

Example: Fucus evanescens.

Note: Fucus also shows a dimorphism of the gametangia, and belongs to a more advanced stage of sexual evolution, but its female gametes represent a condition which is just a stage below the final evolutionary development of sexual cells.

5. The stage representing the attainment of typical female and male, plant gametes, showing the normal primary sexual dimorphism. Female gamete or egg—large, stationary (not discharged from the gametangium), with abundant cytoplasm and food supply; male gamete or sperm—small, free-swimming with cilia, and with a small amount of cytoplasm and food.

Examples: Volvox, Sphæroplea.

6. Hermaphroditic condition with a definite dimorphism showing in the gametangia but not in the contiguous regions or only to a very slight extent. In these plants the sex is determined in the incipient gametangia.

Examples: Monoblepharis, Vaucheria sessilis, Coleochæte.

7. Hermaphrodites having a greater or less area of tissue immediately beyond the gametangia proper showing sexual dimorphism. The sexual state is determined in the tissues before the definite origin of the gametangia and so influences the morphological expression in the tissues below them.

Examples: Chara, Nitella.

8. Hermaphrodites having considerable areas of their bodies differentiated as male or female tissues or branches from which only spermaries or ovaries are produced. The sex is determined in the vegetative tissue or branch long before gametangia are developed.

Examples: Vaucheria synandra, Oedocladium protonema. Fucus evanescens.

9. The culmination stage in the series represented by unisexual individuals of various degrees of intensity and stability of the male or female state and showing some dimorphism in the entire individual. The sexual state in such individuals is determined either in the gametes before fertilization, in the zygote, or in a very early stage after germination of the zygote. There are probably two progressive phases, which, however, can usually be determined only by experiment: (*a*) Species in which sexuality is not strongly fixed, that is the hereditary constitution is such that a reversal of the sexual state is readily brought about in the individual. (*b*) Species in which the sexual state, either male or female, seems to be strongly fixed in the individual, so that it becomes difficult to change from one sexual state to a neutral state or from one sexual state to the other.

Examples: Oedogonium lautumniarum, Fucus vesiculosus, Mucor stolonifer (specialized sexual condition).

III. HOMOSPOROUS SERIES WITH ANTITHETIC ALTERNATION OF GENERATIONS.

In this series the sporophyte shows no sexual differentiation whatever, but in some species there may possibly be a physiological difference in the spores with some cytological dimorphism, as a chromosome difference, for example. The sporophyte is nonsexual in expression in every respect although it carries sexual potentialities in its cells in a latent condition. These potentialities become evident in such abnormal cases as apospory. The sporophyte in normal conditions is entirely neutral in respect to sex, while the gametophyte shows all gradations from hermaphrodites with closely associated sex organs to extreme, unisexual individuals.

10. The lowest stage of this series is represented by species with haploid, hermaphroditic gametophytes having the ovaries and spermaries closely associated. Examples: many liverworts and mosses (synoicous condition).

11. Haploid gametophytes which are hermaphrodites, but which have distinctly differentiated male and female areas. Examples: many ferns, mosses, and liverworts as Lophocolea heterophylla (paroicous condition).

12. Haploid hermaphroditic gametophytes which have the male and female organs on distinct branches or axes. Examples: many liverworts, bog-mosses, and mosses, as Phascum cuspidatum (autoicous condition).

There are, of course, practically all possible intergradations between stages 10, 11 and 12.

13. Haploid gametophytes differentiated into male and female individuals (unisexual) but which may be reversed in sex, either normally through age and growth or artificially by being subjected to the proper environment.

Examples: Equisetum arvense, Matteuccia struthiopteris.

Note: There are also many species especially among the liverworts and mosses which have part of the individuals unisexual and part hermaphroditic (imperfectly unisexual), as Cephalozia curvifolia.

14. Haploid gametophytes differentiated into male and female individuals and these apparently not reversible by known experimental means or reversible only rarely; often showing a high degree of sexual dimorphism; in a few cases at least, but apparently not often, with a difference in size of synaptic chromosomes which are associated with the two sexes.

Examples: Sphærocarpus, Marchantia, Polytrichum.

Note: Marchantia polymorpha is occasionally hermaphroditic.

IV. HETEROSPOROUS SERIES WITH ANTITHETIC ALTERNATION OF GENERATIONS, THE GAMETOPHYTES BEING UNISEXUAL AND THE SPOROPHYTE INDIVIDUALS BISPORANGIATE OR MONOSPORANGIATE.

In this series the sporophyte shows dimorphism at least in the spores and sporangia. The gametophyte generation is apparently always unisexual with distinct male and female individuals highly differentiated both in morphological and physiological characteristics. Normally, the sexual state of the gametophytes is irreversible and determined even before the spores are produced from which they originate.

15. The lowest stage of this series is represented by plants whose bisporangiate sporophytes have only a slight dimorphism; only the spores and sporangia are differentiated and show male and female expression. The two kinds of sporangia are developed side by side on the same leaflet and sorus. The sexual expression is controllable to a slight extent by artificial means.

Example: Marsilea.

Note: It must be remembered that this condition is evolving from a sporophyte that shows absolutely no sexuality in morphological expression in any part of its body but that its cells are, nevertheless, potentially sexual, the gametophytes possessing a high degree of sexual dimorphism.

16. The first advance on the preceding condition is slight but important. This stage is represented by bisporangiate sporophytes with distinct microsporangiate and megasporangiate sori which develop into sporocarps but on the same leaf and which may be side by side. The sexual state is determined considerably earlier than the incepts of the sporangia in the group of cells or in the tissues from which the entire sorus is developed. The given sexual state must, however, be rather weak at first since vestiges of the opposite organs appear.

Examples: Azolla caroliniana and Salvinia natans.

Note: The megasporangiate sorus of Azolla contains vestigial microsporangia and the microsporangiate sorus contains a vestigial megasporangium, plainly showing that the monosporangiate condition of the sorus was derived from an original bisporangiate sorus as in Marsilea, the beginning of the sexual state being thrown back to some extent. The change from one sexual state to the other in the incipent sporangia inhibits the full development.

17. Bisporangiate sporophytes with the entire sporophylls more or less differentiated and with but one kind of sporangia, but the sporophylls arising side by side from a common stem tissue. The typical state of the higher plants.

Examples: Selaginella, Bennettitites, Magnolia, Aquilegia, Lilium, Cypripedium, Lactuca.

18. Monecious sporophytes in which the entire floral axis with its parts is differentiated, the staminate and carpellate flowers commingled more or less closely and showing large vestiges of the opposite set of organs.

Examples: Cocos, Aesculus.

Note: The suppression of the opposite set of sporophylls is of every degree, from this stage on, and has no relation to the area of tissue involved in the sexual differentiation. There are species in which the axis of the inflorescence is at first neutral and gives rise to bisporangiate flowers below and then changes above to a condition leading to the male state when only staminate flowers are produced.

Example: Lophotocarpus calycinus. Such species have an intermediate position between stages 17 and 18.

19. Monecious sporophytes having the axis of the inflorescence differentiated, the staminate flowers being developed first and, by a reversal of the sexual state, the carpellate later, or more commonly the carpellate flowers first and the staminate later.

Examples: Cymophyllus fraseri, Carex nardina, Tripsacum dactyloides, Zizania aquatica, Ricinus communis, Musa sapientum, Stillingia sylvatica. Typha latifolia.

In such inflorescences bisporangiate or abnormal flowers frequently appear on the neutral transition zone where the sexual state changes from one condition to the other.

20. Monecious sporophytes having an entire branch or inflorescence determined as staminate or carpellate.

Examples: Carex lupulina, Euchlæna mexicana, Zea mays (normal form).

21. The lower type of diecious sporophytes having only a moderate reduction in the size of the opposite sporophylls in the monosporangiate flowers, with frequent reversals to the opposite sexual condition—staminate plants developing carpellate flowers and carpellate plants staminate flowers.

Examples: Acer platanoides, Acer rubrum.

There are, of course, interesting intermediate developments, as for example one type of individuals may be monecious and the other purely staminate. An example of this condition is Arisæma dracontium.

22. Diecious sporophytes with complete or nearly complete suppression of the opposite set of organs, in normal cases in all the flowers of an individual, and having a more or less decided vegetative dimorphism. These diecious sporophytes often have a considerable percentage of intermediate individuals or are known by experiment to show frequent reversals in sexual expression, either through mutations, or through the influence of the environment.

Examples: Arisæma triphyllum, Morus alba, Morus rubra, Cannabis sativa, Humulus japonicus, Mercurialis annua.

23. The last and most extreme type with diecious sporophytes apparently without intermediates and not readily or not at all reversible in sexual expression. When the sexual state is once established, the staminate plants remain pure staminate and the carpellate pure carpellate.

Examples: Acer negundo, Populus deltoides, Fraximus americana.

Note: As stated, by such species is represented the extreme limit of evolution in relation to sexual expression. The gametophyte consists of pure male and female individuals apparently irreversible in the normal environment, and the sporophyte consists of pure staminate and carpellate individuals whose sexual state is apparently fixed in their normal environmental conditions. It is probable, however, that all diecious sporophytes will be found reversible as to sex under the proper environment during development. In these plants both the gametophytes and sporophytes are dimorphic. The sexual state of the gametophyte is determined in the previous sporophyte generation and the sexual state of the sporophyte is determined either in the gametes before fertilization, in the zygote at the time of fertilization, or in the embryo after the germination of the zygote.

DISCUSSION OF THE FOREGOING SERIES.

From a study of the preceding series of species and their numerous near relatives, from the lowest manifestation of sexuality to the highest, it becomes evident that sexuality in respect to its influence on the morphology of the vegetative structures has been a gradual evolution making a slow and almost uniform progress to the ultimate species, while the evolution of the gametes, although also showing fundamentally a similar progression, was attained very early, so that usually, when one passes a little beyond the unicellular forms and simple filaments, one finds the same general differences between eggs and sperms as are present in the highest types. The most remarkable thing about the whole evolutionary progression is the fact that very rarely does any step in advancement have any direct relation either to the reduction or to the fertilization stage. So it comes about that the determination of the sexual state takes place in the vast majority of cases in the vegetative tissues, at other times than the periods of reduction and fertilization. On the other hand, since hereditary factors are apparently properties of chromosomes, the characters of the individual outside of its sexual state are in the vast majority of cases predetermined by reduction and fertilization. The environment merely determines the degree of hereditary expression or the time of the expression in the life history.

We can then postulate the phenomena of sexuality as distinct from hereditary units. Probably ordinary hereditary units are irreversible properties of specific parts of the chromatin and cannot be changed except by mutation, while sexual states are due to fundamental properties of the protoplasm or its secretions due to a chemical or physical condition of the molecules or atoms and so any given organic structure may pass from the female to the neutral and then to the male state, or in any direction from one of these states to the other without any change in the hereditary factors whatever.

Cells may, therefore, be absolutely nonsexual or potentially sexual. The potentially sexual may be in the male, female, or neutral state in varying degrees of intensity. It has been the practice of morphologists to designate individuals and generations in an antithetic cycle as "nonsexual" and there is no special objection to this although "neutral" individual or generation might perhaps define the condition somewhat better, but objections might also be raised to this term as applied to heterosporous sporophytes. If we designate individuals by the kind of reproductive cells they produce, then there is no confusion in designating the sporophyte as "nonsexual." It is probably best at present to hold that the lowest forms are entirely nonsexual and not merely neutral, because their protoplasts apparently do not have the proper complexity of organization which would permit of or lead to sexual states.

The first differentiation then, as shown above, is in the gametes themselves, and apparently the most fundamental manifestation of sexuality is one of reaction or attraction of two cells (gametes) toward each other. If the sexual state arises in a cell, destined to be a gamete, after its morphological expression is practically completed then there can be no structural dimorphism, but the earlier the maleness or femaleness is established in the cell the more extreme the dimorphism must become. Since there can be only a short transition between the two extremes of isogamy and heterogamy the normal heterogamous state is soon attained, often with little or no advance in the evolution of vegetative parts, as stated before. The typical egg as has long been known, is comparatively large with a large amount of cytoplasm and food content and is nonmotile, lacking cillia and flagella, while the sperm is small and motile, being provided with cilia or flagella. These distinctions are true for the great majority of types of plants and animals, from the lowest heterogamous species to the highest. The greatest deviation is in respect to the motile organs of the sperm, which are absent in the rhodophyta, strobilophyta, and anthophyta. In other respects, however, the typical dimorphism is not materially altered. Secondary sexual characters begin to appear when a given sexual state is established in the neutral vegetative cells whose descendants are not all transformed into gametes or when a given sexual state is established in cells which are destined to produce vegetative structures only or at least before the final gamete-producing tissue is developed. Finally the dimorphism may involve the entire individual. In this case the sexual state must be present in the spore from which the individual develops or soon after its germination. The conditions which determine whether a cell or tissue shall pass into the male or female state are probably diverse, but favorable and unfavorable nutritive conditions and maturity or senility seem to be among the most important factors. Disturbances brought about by unequal distribution of autosomes or characteristic distributions of allosomes appear also to be conditions bringing about or influencing sexual states, probably by an influence on the metabolism of the cell. Besides these cases in which sexual states are associated with slight differences in chromosome numbers are those in which a haploid or diploid set may be associated with one sex or the other. It is well-known, however, that doubling the number of chromosomes in a gametophyte does not necessarily disturb the sexual condition. It would appear that in cells with allosomes sex reversal should be more difficult to bring about than in cells which have equal distributions of chromosomes, but this is for future experiments to determine. It is well known that in numerous cases secondary sexual characters are reversed in spite of the presence of allosomes. The probable reason that secondary sexual characters become more prominent in the higher forms is because the protoplast contains a greater number of hereditary factors which can be influenced by the sexual state at the time of their expression of characters.

It becomes evident that sex cannot be associated primarily with special chromosomes. The hypothesis of homozygous or heterozygous combinations as determiners and controllers of any given sexual state falls entirely outside of the complex phenomena to be explained. Neither hereditary factors for sex nor factors which control sex are in evidence; for in the vast majority of plants the sexual state is determined in the somatic cells in which neither segregation nor association of chromosomes is taking place. So far as the gametophyte is concerned, after passing through the evolutionary phase where hermaphrodites are the rule, it is illuminating in the highest degree to find that when the complete segregation of sex was attained in the gametophyte it was not at all by the separation of units with sexual control in the reduction division, but at a different stage of the life cycle, namely, in the vegetative cells of the sporophyte. Thus the megasporocytes do not segregate maleness from femaleness nor any properties or hereditary factors which exercise a control over sexual expression, but all the cells of a megasporocyte are differentiated with femaleness, and give rise to female gametophytes, and in the same way the microsporocytes give rise to four microspores, as the result of reduction, and all of the four develop into male gametophytes. The reduction division in this case as in others segregates the chromosomes with their complements of Mendelian factors, but sexuality is not involved in such segregation and is not affected or changed by it. It is, therefore, self evident that fundamental sexual phenomena are caused by properties in plants entirely apart from Mendelian units.

The specific structures and functions developed in the ontogeny of an organism appear to be conditioned on the interaction of four fundamental influences: (1) the hereditary factors themselves, apparently properties of the chromosomes; (2) the influence of the environment, both external and internal; (3) the progression of senility, probably including a fundamental exhaustion and degeneration of the protoplast as well as retardation or change of its activities due to chemical deposits; and (4) the presence of sexual states in the living substance, through which primary and secondary sexual characters and functions are produced and which are probably positive and negative states of atoms or molecules contained in the living cell.

A NEW SPECIES OF PLEA (HEMIPTERA-NOTONECTIDÆ)*

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The genus *Plea* of Leach, Trans. Linn. Soc. London, XII, 1817, pp. 11 and 13, is represented in North America by a single described species, *Plea striola* Fieber. During the past summer, 1921, the writer collected seven specimens of an apparently undescribed species in a small stagnant pond near Fayette, Miss. The insect is named in honor of Prof. R. W. Harned, who is taking a very active interest in the insect fauna of Mississippi.

Plea harnedi n. sp.

Yellowish gray, the fuscous markings large and prominent. Size small, not twice as long as broad, smooth, somewhat shining, quite coarsely and rather closely punctured, many of the punctures with a very short, inconspicuous, decumbent hair (visible under the high power of binocular). Dorsal surface somewhat flattened at the scutellum. Elytra short, of a uniform structure, very declivous posteriorly, each elytron, like in *P. minutissima* (Fussl.) of the Palæarctic region, divided into two distinct areas, the clavus and the corium. Wings well developed, folded beneath the elytra and thus entirely concealed from view when not in use. Head strongly punctured, with a large median, triangular, brown or fuscous area between the eyes. The eyes reddish brown or black. Scutellum fuscous, the apex yellowish gray. Pronotum largely fuscous, a median rectangular spot back of the collum, the sides and posterior margin yellowish gray. The fuscous areas of the elytra and pronotum slightly variable in size. Rostrum and body beneath blackish. Legs yellowish brown, the coxæ and trochanters blackish, the tips of the femora and of the third tarsal segments fuscous. Posterior legs with numerous hairs along the inner margins. Length, 2.27 mm.; width, 1.2 mm.

Seven specimens, taken in a small artificial pond, July 23, 1921, a few miles from Fayette, Miss. *Type* in my collection. *Paratypes* in the National Museum, Mississippi Agricultural College and my collection. As the species is very distinct and

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* Contributions from the Department of Entomology, the New York State College of Forestry, Syracuse, N. Y., No. 38.

not easily confused with *striola*, I have not injured a couple specimens of the type series in order to figure male and female genitalia.

P. harnedi n. sp. may be readily separated from *P. striola* Fieb. by the conspicuous color markings, the large triangular (brown or fuscous) are between the eyes, and each elytron is divided by a very deep suture into two regions. In *striola* the elytra are usually entire and the color, save a small median streak between the eyes, is nearly a uniform yellowish gray; the elytra are also more highly arched behind and quite differently punctured. According to Dr. Hungerford the structure of the elytra in *striola* (suture distinct or not) is a variable character and not a satisfactory one. He states that some specimens of *striola* in the National Museum show a distinct suture (clavus present) and that in others it is pretty hard to make out at all. My specimens of *striola* from Canada, Ohio, New York, Pennsylvania, Florida and Mississippi, fail to show a distinct clavus.

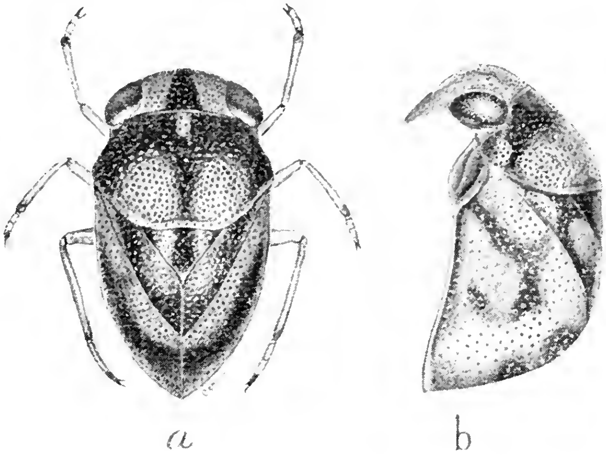

Fig. 1. *Plea harnedi* n. sp. *a*, dorsal aspect; *b*, lateral aspect. From drawing by W. P. Osborn.

A number of other rather interesting aquatic and semiaquatic Hemiptera were taken in the same pond, near Fayette, Miss. In company with *P. harnedi* the writer collected specimens of *Ranatra fusca* P. S. (Bueno & Montd.), *Notonecta-howardi* Bueno, *Corixa* n. sp. (*fide* Hungerford), *Benacus griseus* (Say), *Belostoma flumineum* Say, *Belostoma lutarium* (Stal), *Pelocoris femoratus* (P. B.). The following species were quite common upon the surface of the water: *Mesovelia mulsanti* White, *Hydrometra martini* Kirk., *Hydrometra australis* Say, *Gerris canaliculatus* Say, *Tenagogonus hesione* Kirk., *Trepobates pictus* (H. S.), *Microvelia hinei* Drake, *Velia brachialis* Stal, and *Merragata brunnea* Drake. *Micracanthia humills* (Say) was captured upon some floating aquatic plants and *Gelastocoris culatus* Fabr. was quite common upon the moist ground bordering the pond.

AN ANNOTATED LIST OF MISSISSIPPI CHRYSOMELIDÆ.

H. L. DOZIER
State Plant Board of Mississippi

While engaged in general scouting and inspection work in Mississippi during the past year the writer took advantage of the spare moments to collect and study the chrysomelids. The resultant annotated list is given as an incentive to a more complete one. Thanks are due to Dr. E. A. Schwarz and Charles Dury for confirmation and identification of the specimens. Those not otherwise credited were collected by the writer.

Lema brunnicollis Lac. Agr. College, Miss., April 7, 1920, A. V. Smith coll.; Okolona, July 9, 1921, M. R. Smith; Pascagoula, August 5, 1921.

Lema trilineata Oliv. Rosebloom, Miss., Summer of 1915, R. Buchanan; Agr. College, Miss., April 10, 1920, D. V. Stapleton.

Lema sexpunctata Oliv. Ocean Springs, C. Forkert; Agr. College, May-June, 1920; Vicksburg, July 15, 1921.

Lema sayi Crotch. Agr. College, March-April.

Antipus (Anomaea) *laticlavia* Forst. Blue Mountain, July 2, 1914, H. H. Carter; Vimville, August 1, 1914, E. R. Rainey; Agr. College, May-Sept.

Babia quadriguttata Oliv. Agr. College, April-May.

Saxinis omogera La. Longview, June 27, 1920; Agr. College, July 20, 1920, A. McIntosh; several specimens.

Chlamys plicata Fab. Pascagoula, July 10, 1920, swept in abundance from floor of low pine flatwoods; Helena, July 13, 1920; Aberdeen, April 5, 1921, sweeping in pine woods.

Exema gibber Oliv. Pascagoula, July 10, 1920, sweeping floor of low pine flatwoods.

Pachybrachys lodingi Fall. Pascagoula, sweeping floor of low pine flatwoods, July 10, 1920.

Pachybrachys atomarius Melsh. Agr. College, S. F. Potts.

Pachybrachys roboris Fall. Agr. College, July 11, 1913, J. G. Hester, on pecan.

Pachybrachys atomarius var. Pascagoula, swept in abundance from floor of low pine flatwoods, July 12, 1920.

Pachybrachys bivittatus Say. Agr. College; Woodville, July 26, 1921, abundant on willow.

Pachybrachys autolycus Fall. Cat Island, several swept from *Juncus* vegetation, September 7, 1920.

Pachybrachys viduatus Fabr. Ocean Springs, July 29, 1920; Longview, a number taken sweeping in deciduous woods, June 27, 1920; Hattiesburg, August 10, 1921.

Pachybrachys viduatus var.? Big Point, July 15, 1920; Pascagoula, June 6, 1920, flatwoods.

Pachybrachys intricatus Suffr. Dennis, June 6, 1921.

Pachybrachys luridus Fabr. Longview, several sweeping in low deciduous woods, June 27, 1920.

Pachybrachys subfasciatus Blatch. Agr. College, June 4, 1915, C. C. Greer.

Pachybrachys hepaticus Melsh. Cat. Island; a single specimen taken sweeping in a stand of *Juncus*, Sept. 7, 1920.

Monachulus (Monachus) *auritus* Hald. Pascagoula, July 10, 1920; Rara-avis, July 5, 1921, M. R. Smith.

Cryptocephalus quadruplex Newn. Agr. College.

Cryptocephalus bivius Newn. Agr. College, September 29, 1915, W. Gernon.

Cryptocephalus venustus Fabr. Longview, June 27, 1920; Agr. College, May-June.

Cryptocephalus obsoletus Germ. Pascagoula, sweeping floor of low pine flatwoods, July 12, 1920, abundant; Helena, July 13, 1920; Maxie, August 19, 1920; Lumberton, August 26, 1920.

Cryptocephalus gibbicollis Hald. Agr. College, January 1, 1915, R. H. Batty; Bradley, July 14, 1921; Poplarville, July 28, 1921; Hattiesburg, August 10, 1921.

Cryptocephalus incertus Oliv. Fruitland Park, sweeping low grass and foliage at edge of gum swamp, August 17, 1920; Hattiesburg, abundant sweeping grassy floor of pine and blackjack oakwoods, August 10, 1921; Pascagoula, August, 1921; Biloxi, August 1, 1921.

Cryptocephalus sp. Maxie, a single specimen of a very small brown species so far unidentified and perhaps new, August 19, 1920; Ocean Springs, August 3, 1921.

Diachus auratus Fabr. Ocean Springs, July 24, 1920; Agr. College, H. E. Weed; Verona, July 9, 1921.

Bassareus brunnipes Oliv. Agr. College, abundant sweeping weeds; June 21, 1920; Big Point, July 15, 1920; Poplarville, July 27, 1921; Gulfport, August 1, 1921.

Chrysodina globosa Say. Rara-avis, July 5, 1921, M. R. Smith.

Nodononta tristis Oliv. Bovina, July 2, 1904, T. D. Kilne; Utica, July 1, 1905, J. B. Dudley; Bassfield, T. N. Gillan.

Colaspis brunnea Fab. Agr. College, common; Millville, June 24, 1904, J. L. Norman; Roxie, June 20, 1910, S. F. Blumenfeld; Utica, June 17, 1920, Blumenfeld; Gloster, June 20, 1920, Blumenfeld.

Colaspis favosa Say. Pascagoula, numbers taken sweeping floor of low pine flatwoods, July 12, 1920; Agr. College, H. E. Weed.

Rhabdopterus picipes Oliv. Longview, sweeping in deciduous woods, June 27, 1920; Fruitland Park, August 17, 1920; Agr. College, June 29, 1915, J. L. E. Lauderdale.

Graphops marcassitus Cr. Pascagoula, a number taken sweeping floor of low pine flatwoods, July 12, 1920; Ellisville, sweeping floor of high pine land, August 24, 1920.

Fidia longipes Melsh. Agr. College, May '93, H. E. Weed; Como, June 12, 1911, M. W. Weston; Natchez, June 8, 1895, H. E. Weed.

Metachroma laevicollis? Cr. Pascagoula, July 12, 1920.

Metachroma quercatum Fab. Big Point, L. Brown, numbers on pecan, April 29, 1915; Big Point, D. Cunningham, abundant on pecan, May 5, 1915.

Tymnes tricolor Fabr. Agr. College, April 16, 1919, J. W. Patterson.

Myochrous denticollis Say. Fayette, April 27, 1910, R. H. Truly; Crystal Springs, May 9, 1910, R. E. Gates; Phillip, May 14, 1910, R. W. Harned; Pascagoula, numbers swept from floor of low pine flatwoods, July 6, 1920; Ocean Springs, July 29, 1920.

Glyptoscelis pubescens Fab. Agr. College, May 6, 1917, C. H. Reems.

Paria canella var. *quadrinottatus* Say. Longview, sweeping in low deciduous woods, April 9, 1921.

Paria canella var. *quadriguttatus* Lac. A number beaten from willow at Nettleton, March 27, 1921.

Paria canella var. *atterimus* Oliv. Pascagoula, July 12, 1920, flatwoods.

Chrysochus auratus Fabr. Agr. College, April 18, 1914, V. E. Critz; Agr. College, October 14, 1914, R. E. Jackson; Oxford, June 16, 1919, F. M. Hull; on Asclepias.

Labidomera clivicollis Kby. Macon, September 16, 1919, J. T. Douglas; Agr. College, April 24, 1917, E. B. Johnson; June 10, 1919, G. B. Ray; October 26, 1920, J. B. Boswell.

Leptinotarsa decemlineata Say. Abundant over most of the State. April-October.

Leptinotarsa juncta Germ. Several taken in State.

Zygogramma suturalis Fabr. Agr. College, March, 1916, R. C. Pittman.

Calligrapha praecelsis Rogers. Agr. College, 1916, G. C. Horton.

Calligrapha philadelphica Lec. Agr. College, April and May; Brookhaven, August, 1919, K. W. Holloway; Maxie, August 19, 1920; Nettleton, March 27, 1921, on willow.

Lina interrupta Fab. Agr. College, April, 1920, B. R. Gunn; Poplarville, May 3, 1921, M. H. Mabry.

Lina scripta Fab. Vimville, August 1, 1914, E. R. Raney; Agr. College, April 2, 1919, M. E. Kelly; Scott, July, 1919, C. H. Brannon; Leflore Co., July, 1919, R. R. Spann; Agr. College, July 20, 1920, A. McIntosh.

Monocesta coryli Say. Agr. College, October, 1895, one adult and two larvæ, H. E. Weed.

Galerucella americana Fab. Pascagoula, July 12, 1920, abundant in sweeping floor of low pine flatwoods; Lyman, July 28, 1921.

Galerucella notulata Fab. Pascagoula, July 12, 1920, several taken in flatwoods.

Galerucella notata Fab. Baxterville, July 27, 1921, sweeping floor of open pine flatwoods.

Diabrotica 12-punctata Fab. Generally distributed over the entire State, attacking corn, beans, alfalfa, etc.

Diabrotica balteata Lec. Agr. College, October 26, 1915, on corn, E. B. Huston; Fayette, October 2, 1916, Mrs. J. C. McNair; Ocean Springs, July 24, 1920; Biloxi, August 12, 1920.

Diabrotica atripennis Say. Okolona, several taken June 26, 1921.

Diabrotica vittata Fab. Laurel, August 2, 1916, M. G. Dyers; Houlka, J. R. Hamilton; Buena Vista, H. L. King; Shubuta, C. E. Brashier; Ratliff, A. McIntosh; Agr. College, F. H. Jones; Aberdeen, April 5, 1921.

Diabrotica tricincta Say. Agr. College, summer 1919, B. H. Virdon. This record is questioned and the specimen is probably from Texas.

Phyllobrotica limbata Fab. Hattiesburg, 1916, H. Cook.

Luperodes varicornis Lec. Kirby, July 10, 1915, on corn in numbers, R. L. Saxon; Johns, July 1, 1915, numerous on corn, D. G. Williams.

Ceratoma trifurcata Forst. Abundant throughout the State on beans.

Blepharida rhois Forst. Longview, May 16, 1914, E. H. Byrd; Agr. College, April-October, on sumach; Amory, March 26, 1921.

Oedionychis gibbitarsa Say. Agr. College, April 16, 1915, A. Berret; May 16, 1915, W. H. Calcata; March 30, 1919, R. L. Price; Pascagoula, July 5, 1920, abundant, sweeping roadside vegetation near river; Agr. College, April 18, 1920, J. N. Crisler.

Oedionychis thoracica Fab. Agr. College, March 20, 1918, R. J. Coker.

Oedionychis vians Ill. Agr. College, October 26, 1918, A. Hammet; Helena, June 13, 1920.

Oedionychis petaurista Fab. Longview, June 27, 1920, several taken sweeping in deciduous woods; Pascagoula, numbers taken sweeping floor of low pine flatwoods, July 10, 1920.

Oedionychis miniata Fab. Pascagoula, July 12, 1920, flatwoods; Agr. College, H. E. Weed; Baxterville, July 27, 1921.

Oedionychis indigoptera Lec. Hattiesburg, August 10, 1921, a single specimen.

Oedionychis thyamoides Cr. Agr. College, abundant April-May; Longview, June 27, 1920; Amory, March 27, 1921; Aberdeen, April 5, 1921; Gibson, June 27, 1921.

Oedionychis suturalis Fab. Shubuta, C. E. Brashier; Big Point, July 15, 1920; Ocean Springs, July 24, 1920.

Oedionychis quercata var. *obsidiana* Fab. Big Point, July 15, 1920; Pascagoula, July 6, 1920, flatwoods.

Oedionychis quercata var. Amory, March 27, 1921; Tibbee, April 5, 1921, abundant on ash.

Oedionychis quercata var. Tibbee, April 5, 1921, abundant on ash.

Oedionychis scalaris Melsh. var. Pascagoula, July 10, 1920.

Oedionychis sexmaculata Ill. Agr. College, April 3, 1921.

Disonycha pennsylvanica Ill. Agr. College, H. E. Weed.

Disonycha caroliniana Fab. var. Baxterville, July 27, 1921, in pine flatwoods.

Disonycha quinquevittata Say. Agr. College, May 5, 1914, K. V. Jones.

Disonycha glabrata Fab. Agr. College, June 23, 1920; Tylertown; Port Gibson, July 21, 1921.

Disonycha abbreviata Melsh. Agr. College, May, 1920, B. Boswell; Woodville, July 25, 1921; Meridian, August 14, 1921.

Disonycha collata Fab. Agr. College, March 29, 1919, A. V. Knight.

Haltica polita Oliv. Baxterville, July 27, 1921, flatwoods; Belmont, June 7, 1921.

Haltica rufa Ill. Longview, June 27, 1920, one specimen taken in deciduous woods.

Lactica ocreata Say. Oxford, summer 1920, F. M. Hull. Abundant on passion flower.

Chalcoides helxines L. Extremely abundant on willow throughout the State.

Crepidodera erythropus Melsh. Agr. College, October 20, 1917, D. Q. Segrest.

Epitrix parvula Fab. Meadville, C. F. Cain.

Epitrix cucumeris Harris. Agr. College, H. E. Weed; Sardis, 1895, T. A. Mitchell.

Chaetocnema pulicaria Melsh. Agr. College, H. E. Weed.

Chaetocnema denticulata Ill. Ocean Springs, July 29, 1920.

Chaetocnema alutacea Cr. Helena, July 13, 1920, sweeping in low pine flatwoods; Big Point, July 13, 1920.

Systena hudsonias Forst. Longview, June 27, 1920.

Systena frontalis Fab. Helena, July 13, 1920.

Systena pallipes Sz. Biloxi, July 30, 1921. A single specimen.

Systena elongata Fab. Fayette, June 18, 1910, S. F. Blumenfeld; Utica, June 17, 1910; Agr. College, June 22, 1920.

Systena taeniata Say. Abundant throughout the State.

Systena marginalis Ill. Longview, June 27, 1920.

Longitarsus testaceous Melsh. Agr. College, October, 1895, H. E. Weed.

Longitarsus melanurus Melsh. Agr. College, H. E. Weed.

Phyllotreta vittata Fab. Agr. College, May 6, 1915, J. W. Bailey. feeding on cabbage; Tupelo, March 22, 1921, in garden.

Phyllotreta picta Ill. Artesia, May 1, 1921, swept from roadside vegetation.

Phyllotreta oregonensis Cr. Natchez, June 8, 1895, H. E. Weed. A doubtful record.

Dibolia borealis Chev. Agr. College, H. E. Weed.

Psylliodes convexior Lec. Agr. College, October and November, 1895, H. E. Weed.

Chalepus nervosa Panz. Agr. College, April 3, 1921.

Chalepus bicolor Oliv. Pascagoula, July 10, 1920; Ellisville, sweeping floor of high pine land, August 24, 1920; Ocean Springs, July 29, 1920; Fruitland Park, August 17, 1920; Golden, June 5, 1921; Baxterville, July 27, 1921; Hattiesburg, August 10, 1921.

Chalepus scapularis Oliv. Agr. College, March 20, 1910, J. L. E. Lauderdale; Longview, sweeping in deciduous woods, June 27, 1920.

Chalepus notatus Oliv. Big Point, July 15, 1920.

Chalepus rubra Weber. Agr. College, July 1911, L. N. Felton; Longview, April 9, 1921, sweeping in low deciduous woods.

Chalepus hornii Smith. Golden, July 5, 1921; Belmont, July 7, 1921, a number of specimens swept probably from a small legume on forest floor.

Octotoma plicatula Fab. Agr. College, April 29, 1921, F. M. Hull; Woodville, July 26, 1921.

Uroplata porcata Melsh. Pascagoula, July 6, 1920, sweeping floor of low pine flatwoods; August 5, 1921.

Microrhopala excavata Oliv. Golden, July 5, 1921, a single specimen taken sweeping floor of open high mixed pine and deciduous woods on hillside; Gulfport, August 1, 1921.

Desmonota variolosa Weber. Columbia, July, Q. E. Morris; Agr. College, several collected on sweet potatoes by J. W. Bailey. As this is a tropical species and not known heretofore from the U. S., I consider both of these records rather doubtful.

Gratiana (Cassida) *pallidula* Boh. Agr. College, May 3, 1921, C. J. Havens.

Coptocycla clavata. Agr. College, May 15, 1921, F. M. Hull.

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SOME SUB-SURFACE ROCK CHANNELS AND CAVITIES FILLED WITH GLACIAL MATERIAL.

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DESCRIPTION OF DEPOSITS.

At Silica, in Lucas County, Ohio, about ten miles west of Toledo, is a large quarry which shows a face about twenty feet in height and about one-fourth of a mile long, extending N-S. and facing east. The strata exposed are in the upper part of the Lucas dolomite and they dip westward at an angle of about five degrees.

Along the south part of this quarry face at about 15 feet beneath the top there was exposed in 1921 a zone of light drab dolomite, three to four feet thick, containing a number of cavities that are lined and partially filled with large crystals of calcite of the dog-tooth form. These spaces, or former spaces now partly filled, commonly appear as lense-shaped in the quarry face and are one to three feet long and six to twelve inches high.

Associated with the dolomite and calcite of this zone there is a considerable quantity of fine grained silt clay. Most of it is greenish or greenish-blue in color, but brown and other dark shades exist. Most of it is laminated, but some is compact without laminæ. It is very tough and when wet sticks to the hammer and tears like putty. When dry it is very hard and breaks with a direct even fracture. Most of this clay is without grit. At many places the clay rests against and fits around the projecting dog-tooth calcite crystals. It was found also in sharp lateral contact with the dolomite and even filling small irregularities in the roofs of the former cavities. The clay exists in masses two to three feet across and in such quantity that in wet weather it causes considerable trouble in the crushing plant, because it clogs in the crushing burrs and prevents the rock from dropping into them. The larger masses are dumped to one side by the steam shovel and not loaded on the cars.

At several places sand is associated with the clay and at a few places there is gravel containing pebbles and cobbles, some of the latter being four to six inches through. The most common rock among the pebbles and cobbles is the Monroe dolomite, but basalts, granitoids and foreign sedimentaries exist. Some of the pebbles are well rounded and some are subangular. All of this material is relatively fresh. Most of the quarry face was a confused mass of blasted stone, but where the form of the clay deposits could be determined it was found that if gravel and sand exist they are at the bottom and at most places are overlaid by the clay. A few cases of very fine sand interbedded with clay exist. Surfaces of projecting dog-tooth calcite crystals are buried in the sand, which can be cleaned away from around the crystals.

One deposit in a tunnel in the rock gives such clear evidence as to deserve special notice. The rock channel is three feet six inches high and two feet wide at the widest part, and is cut across at an angle by the quarry wall. In the bottom is coarse gravel containing some cobbles up to six inches in diameter. Above the gravel is about two feet of compact, tough clay, blue in color, except for six inches at the top, which is oxidized and yellow. Above the clay is an open space about one foot high. The channel extends obliquely into the quarry wall and at a distance of about five feet it broadens out into a space four to five feet across, with about two feet above the filling of clay. Farther in, the channel narrows and the roof comes down until at a distance of about 20 feet from the quarry face there appears to be only four to six inches of space above the filling.

ORIGIN OF DEPOSITS.

As to the origin of the clay deposits, it is evident that they did not originate by weathering in place, but have been introduced in some way. The characteristics of the clay suggest slack-water silt deposits such as are in many cases associated with glacial deposits. The composition and shape of the pebbles and cobbles and the amount of wear show that the gravel is glacial material. How did it come to its present position fifteen feet below the surface and apparently enclosed in the dolomite? The stone above is compact, bedded dolomite without any known natural opening through it. Numerous drill holes have been sunk for blasting the stone and some of these show on the quarry face, but the silt clay is very different from the calcareous slime derived by wash from the drillings and the packing used in the drill holes is distinct from the sand and gravel filling.

The characteristics of abundant calcite, cavities more or less filled with calcite, and the enclosed silt and gravel deposits, are present along the quarry face for more than a hundred yards; that is, these are characteristics of a zone. The strata here dip west into the quarry wall at an angle of about five degrees and if this zone is projected upward it would meet the level of the general rock surface about forty-five yards east of the present quarry wall. In fact, such a position of outcrop is shown at the south wall of the quarry. The cavernous character of this zone continued to the outcrop and it was by these openings that the glacial material entered. The first material carried down and deposited was sand and gravel with cobbles. The coarser material was deposited only in or near the more open channels like the one described above. Some of the sand was carried into the smaller crystal-lined cavities and deposited around the crystals.

The deposition of the clay followed that of the sand and gravel. Much of it is laminated and the material is very fine grained, indicating deposition from relatively quiet water which apparently filled all the cavities of the zone. The deposition continued until the cavities were completely filled, even to the placing of laminated clay in small irregularities in the roofs of the cavities. At other places the cavity filling was only partial or absent entirely.

The ground water level of the region at the present time is about 15 feet beneath the surface and it is evident that these cavities go deeper than this, and in another quarry this same zone contains much calcite filling, although few open spaces, at a depth of 45 feet. It is not known to what depth the introduced glacial deposits extend, but their presence at 15 feet below the surface and the calcite filling at greater depth show that the region was higher and the ground water surface deeper at the time of the formation of the cavernous zone and probably at the time when the gravels were carried down the passages on a general five degree gradient. The clay on the other hand gives evidence that the channels were filled with water at the time of the clay deposition. This indicates a higher water table, or deposition at the time that the region lay beneath Lake Maumee and its successors. The general similarity of these clays to the clay deposits of the old lake bottom adds support to this latter interpretation. As the waters of the lake bottom at this place were agitated, the fine silt settled down into the water of the channels beneath, which were more or less connected with the lake, and in these channels and the connected rock cavities the clay deposition took place.

Two miles north of Silica a quarry, exposing the same horizons as at Silica, shows this same cavernous zone with crystal lined cavities. A fine grained clay was observed in the cavities at eight feet below the rock surface and a workman reported that they had found some very tough and sticky clay in the cavities of this zone at 15 feet below the rock surface. This clay is undoubtedly of the same type and origin as that at Silica.

Considerable masses of tough, fine grained clay were seen associated with the loose blocks of stone on the quarry faces at the Holland quarry, seven miles south of Silica and at the France Stone Company quarry, one mile south of Monroe, Michigan. The clay was much like that seen at Silica, but in neither of these places could it be so definitely connected with a glacial origin.

THE CLASSIFICATION OF PLANTS. XII.*

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Eleven papers have been published previously by the writer, giving a preliminary survey of the phyletic classification of plants, and covering the whole ground except the Algæ. The first paper was published in the OHIO NATURALIST, 5: 298-301, 1905, and subsequent papers appeared from time to time in that journal. The present paper completes the series, but it is the intention of the writer to continue the studies in a more detailed manner, dealing with the phylogeny and taxonomy of the various classes and subclasses.

The term Algæ has reference to a physiological group and is of the same convenience in dealing with the lower plants in a practical way as the terms, trees, parasites, herbs, etc. It has no taxonomic value. An alga may be defined as a thallophyte with chlorophyll. The algæ are largely aquatic organisms but some species are able to endure aerial conditions as their normal habitat.

The algæ apparently belong to at least six distinct phyla and a number of the classes have closely related fungi. Our knowledge of the morphology and life histories of the algæ is still very imperfect, so any arrangement must be regarded as more or less tentative. The writer has not been able to follow those authors who divide the green algæ primarily into Akontæ, Isokontæ, and Heterokontæ. Such a procedure seems decidedly artificial. The Peridinieæ are regarded as more animal-like than plant-like and are thus removed to the Protozoa. Following Oltmanns and others, the Diatomeæ are placed near the Conjugatæ but only as a subphylum, since the relationship can, at best, be only very remote. The agreement with desmids in certain characters is nevertheless striking and both diatoms and desmids may be regarded as derivatives from some primitive filamentous group without zoospores, but which discharged its isogamous sexual cells into the water with little change from the vegetative character. Although the Oedogoniales are

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peculiar in many respects they are nevertheless plainly related to the other filamentous green algæ and the same is true of the Siphoneæ and related forms which according to the writer's views do not warrant segregation into a distinct phylum as was done by Bessey. On the other hand, the Charales are so aberrant that their origin is very obscure and they have, therefore, been placed in a distinct phylum.

SYNOPSIS OF THE ALGAL PHYLA

I. Cells typically with poorly differentiated nuclei and chromatophores, reproducing by fission, motile and nonmotile, never with a pure chlorophyll-green color, but containing phycocyanin; unicellular or filamentous, apparently without sexuality. The most primitive of the algae and along with the bacteria the most primitive of all organisms. Marine or mostly freshwater, some species growing in very hot springs. Phylum, SCHIZOPHYTA.

II. Cells with well differentiated nuclei and usually with definite chromatophores; green or variously tinted by coloring matters.

  A. Unicellular or filamentous plants containing chlorophyll, either of a brownish or yellowish color and with silicified, two-valved walls, or green with complex chromatophores or fantastic cells, the walls not silicified; sexual or apparently nonsexual by degeneration; conjugating cells not ciliated, isogamous. Phylum, ZYGOPHYTA.

    1. With silicified, valved cell walls, usually with fantastic forms and markings, and usually of a yellowish or brownish color. Marine and fresh water plants. Subphylum, DIATOMEAE.

    2. Cell walls not silicified; plants filamentous or unicellular, green, the unicellular often with fantastic forms and markings. Fresh water plants. Subphylum, CONJUGATAE.

  B. Plants not with silicified two-valved walls; usually with zoospores when green, or with heterogamous sexuality, sometimes nonsexual, the isogamous green forms usually not with fantastic chromatophores nor with a constriction in the middle of the cell.

    1. Antheridium when present not consisting of a globular structure containing sperm-bearing filaments; sometimes with an alternation of generations.

      a. Plants mostly green, nearly all producing nonsexual zoospores, the sexual forms isogamous or heterogamous. Characteristic water plants, but also numerous marine species. Phylum, GONIDIOPHYTA.

      b. Plants with the chlorophyll usually hidden by a brown, red, or purple pigment always with a multicellular body and with sexuality or apparently from sexual ancestors.

        (a) Mostly marine, often large, brown algae with phycophaein; isogamous or heterogamous or sexuality unknown, with ciliated sperms, both gametes discharged from the gametangium. Phylum, PHAEOPHYTA.

        (b) Mostly marine red or purple algae with phycoerythrin; heterogamous, with stationary eggs and non-ciliated sperms. Phylum, RHODOPHYTA.

    2. Filamentous, green algae with globular antheridia containing sperm-bearing filaments, the sperms being biciliated; nonsexual spores absent. In fresh or brackish water. Phylum, Charophyta.

SYNOPSES OF THE SEVERAL PHYLA

Phylum, Schizophyta. Fission Plants.

I. Without a definite nuclear membrane and with a low type of chromatophore. Class, Cyanophyceae. Blue-green Algae. 1000 species.

  A. Not filamentous; cells free or in masses or plates (superficial aggregates); or the cell individuals with definite base and apex, in fruiting sometimes forming a row of cells. **Chroococcales.** Chroococcaceae, Chamaesiphonaceae.

  B. Cells arranged in definite filaments.

    1. Filaments without hair-like tips, sometimes narrowed at the ends.

      a. Without heterocysts; free filaments commonly massed into flat layers, sometimes several filaments enclosed in one common sheath. **Oscillatoriales,** Oscillatoriaceæ.

      b. With intercallary heterocysts. **Nostocales.** Nostocaceæ, Scytonemataceæ, Stigonemataceæ.

    2. Filaments with hair-like tips at one or both ends. **Rivulariales.** Camptotrichaceæ, Rivulariaceæ.

II. With nuclear membrane and highly differentiated chromatophores; unicellular or in colonies. Class, Glaucocysteæ. 20 species. **Glaucocystales,** Glaucocystaceæ.

Phylum, Zygophyta. Conjugate Algæ.

I. Cell walls impregnated with silica, composed of two valves; chromatophores yellow or brown, rarely green, containing chloraphyll and diatomin and a variable number of pyrenoids. Subphylum and class, Diatomeæ. Diatoms. 5700 species.

  A. Valves without a raphe or pseudo-raphe, with a concentric or ratiating symmetry around a central point; valve view usually circular, polygonal, or broadly elliptical in outline, rarely boat-shaped or irregular; conjugation unknown; cells without spontaneous movement. Mostly marine plants. **Eupodiscales.** Round Diatoms. Eupodiscaceæ, Soleniaceæ, Biddulphiaceæ, Rutilariaceæ.

  B. Valves with a raphe or pseudo-raphe or with a sagittal line, with a zygomorphic or isobilateral or sometimes irregular symmetry; never centric; valve view mostly boat-shaped or elliptic in outline; motile or nonmotile; conjugation known in most groups. Mostly fresh water plants. **Naviculales.** Long Diatoms. Fragillariaceæ, Surirellaceæ, Achnanthaceæ, Naviculaceæ.

II. Cell walls without silica, but with abundant development of gelatinous pectose causing the plants to be slimy to the touch; chromatophores green, with chlorophyll and one or more pyrenoids. Subphylum and class Conjugatæ. 2300 species.

  A. Thallus a filament, or commonly separating into single cells, mostly flattened, the cell wall usually divided into two symmetrical halves; cells mostly constricted at the middle, often of fantastic and beautiful forms; cell contents mostly divided into symmetrical halves; conjugation by the breaking open of the cell walls or by the formation of a primitive conjugation tube. **Desmidiales.** Desmids. 2100 species. Spirotaeniaceæ, Desmidiaceæ.

  B. Thallus a simple filament, occasionally slightly branched, of cylindrical cells, the cells not constricted in the middle, but sometimes the contents divided into symmetrical halves; these latter forms distinguished from the preceding order by the definite filament and prominent conjugation tube; some species forming aplanospores. **Zygnemales.** Pond-scums. 200 species. One family, Zygnemaceæ.

Phylum, Gonidiophyta. Zoospore Plants.

SYNOPSIS OF THE CLASSES OF GONIDIOPHYTA.

I. Plants unicellular or colonial, not truly filamentous.

  A. Nonsexual, unicellular or colonial algæ without zoospores, commonly with autospores; cells normally with one nucleus. Autosporæ.

  B. Isogamous or heterogamous, sexual algæ or probable derivatives from them, with zoospores.

    1. Unicellular or colonial algæ, usually with one nucleus in each cell, rarely cenocytic; the colonial forms not produced by the symmetrical aggregation of free zoospores into a definite colony; vegetative stage nonmotile or active. Isogamus or heterogamous. Chlorococceæ.

    2. Cenocytic algæ consisting of colonies of peculiar form, new colonies being produced by the definite arrangement of daughter cells developed in the parent cenocyte; isogamous, aquatic. Hydrodictyeæ.

II. Green algæ with a filamentous or massive body and with 1, 2, 4, or many cilia on the zoospores and gametes.

  A. Cenocytic, septate or nonseptate, isogamous or heterogamous.

    1. Vegetative body usually septate, consisting of a series of cenocytes; chloroplasts forming a net, rarely in separate plates. Siphonocladeæ.

    2. Vegetative body usually nonseptate, with distinct lenticular, oval or plate-like chloroplasts. Siphoneæ.

  B. Algæ having normal cells with one nucleus, with a conjugation of free swimming gametes or with motile sperms and stationary eggs. Conferveæ.

Class, Autosporæ. 200 species.

I. Reproduction by autospores, the protoplast dividing within the mother cell, and the daughter cells escaping singly or in colonies. In fresh, brackish, or sea water, or on moist rocks, etc.; some endozoic in water animals. **Selenastrales.** Selenastraceæ, Oocystaceæ, Chlorellaceæ, Tetraedraceæ, Scenedesmaceæ, Sorastraceæ.

II. Reproduction by vegetative division and separation by splitting of the daughter cells. (Doubtfully placed in the Autosporæ). Aerial, on damp stones, trees, etc., or in fresh or salt water. **Protococcales.** Protococcaceæ.

Class, Chlorococceæ. 250 species.

I. Cells ciliated and motile in the vegetative state; unicellular or in definite colonies. **Volvocales.** Chlamydomonadaceæ, Volvocaceæ.

II. Cells not active in the vegetative stage.

  A. Vegetative cell divisions absent, cells separate or somewhat cenocytic. **Chlorococcales.** Chlorococcaceæ, Chloretheciaceæ, Ophiocytiaceæ.

  B. Colonies increasing by vegetative cell division. **Tetrasporales.** Botryococcaceæ, Tetrasporaceæ.

Class, Hydrodictyeæ. 30 species.

One order, **Hydrodictyales.** Pediastraceæ, Hydrodictyaceæ.

Class, Siphonocladeæ. Lower Tube Algæ. 450 species.

I. Plants isogamous or slightly heterogamous; filaments branched. **Cladophorales.** Valoniaceæ, Cladophoraceæ, Siphonocladaceæ, Dasycladaceæ.

II. Plants heterogamous, with stationary eggs and motile spermatozoids; filaments septate, unbranched, free-floating. **Sphaeropleales.** Sphaeropleaceæ.

Class, SIPHONEÆ. Higher Tube Algæ. 200 species.

- I. Sexual reproduction unknown or isogamous.
  - A. Small globular terrestrial plants with branched rhizoids penetrating the ground; zoospores with cilia of unequal lengths. **Botrydiales.** Botrydiaceæ.
  - B. Mostly large marine or sometimes endophytic algæ; zoospores if present not with unequal cilia. **Bryopsidales.** Derbesiaceæ, Bryopsidaceæ, Caulerpaceæ, Phyllosiphonaceæ, Codiaceæ.
- II. Sexual reproduction by highly specialized stationary eggs and motile spermatozoids; thallus tubular, branched or unbranched; growing in fresh or brackish water or on moist soil. **Vaucheriales.** Vaucheriaceæ.

Class, CONFERVEÆ. Confervas. 650 species.

- I. Isogamous, or the free-swimming gametes sometimes of unequal size.
  - A. Thallus unbranched.
    - 1. Chloroplasts reticulate, without pyrenoids; fresh water plants. **Microsporales.** Microsporaceæ.
    - 2. Chloroplasts central or parietal, with one or more pyrenoids.
      - a. Chloroplast single, central, stellate, with one pyrenoid; no zoospores known; aerial in habit. **Prasiolales.** Prasiolaceæ.
      - b. Chloroplast parietal, with one to many pyrenoids.
        - (a) Unbranched filaments; chloroplasts with one to many pyrenoids. **Ulotrichales.** Ulotrichaceæ, Tribonemaceæ.
        - (b) Thallus expanded, a 1-2-layered plane or tube; chloroplast single, with 1 pyrenoid; mostly marine. **Ulvales.** Ulvaceæ.
  - B. Thallus filamentous, branched, usually abundantly so, the branches often attenuated or hair-like tips. **Chaetophorales.** Chaetophoraceæ, Trentepohliaceæ, Harposteiraceæ.
- II. Heterogamous, the egg stationary in the oogonium; sometimes with a primitive alternation of generations.
  - A. Oogonium not developing a cortical layer after fertilization. **Oedogoniales.** Cylindrocapsaceæ, Oedogoniaceæ.
  - B. Oogonium with a trichogyne-like tip, covered after fertilization by a cortical layer; thallus disk-like or cushion-like. **Coleochaetales.** Coleochaetaceæ.

Phylum, PHAEOPHYTA. Brown Algæ.

- I. Zoospores present; sexual reproduction by motile, biciliate gametes produced in external gametangia, occasionally by heterogametes, and in extreme cases by nonmotile eggs. Class, PHAEOSPORÆ. Kelps. 550 species.
  - A. Zoospores and isogametes similar and motile.
    - 1. Frond various, simple or branched, but never differentiated with definite root-like and leaf-like parts. **Ectocarpales.** Ectocarpaceæ.
    - 2. Frond large, leather-like, usually stalked, differentiated with root-like and leaf-like parts; with zoospores only. The largest marine plants. **Laminariales.** Laminariaceæ. Giant Kelps.
  - B. Zoospores and heterogametes dissimilar.
    - 1. Gametes large and small, but both motile. **Cutleriales.** Cutleriaceæ.
    - 2. Gametes consisting of small active spermatozoids and nonmotile eggs; frond filiform. **Tilopteridales.** Tilopteridaceæ.
- II. Zoospores absent; sexual reproduction by means of motile sperms and nonmotile eggs which are discharged from the oogonium; nonsexual reproduction absent or by means of nonmotile spores.
  - A. Sperms biciliate; without nonsexual spores; gametangia in sunken conceptacles. Class, CYCLOSPORÆ. Rockweeds. 350 species. One order **Fucales.** Durvillaeaceæ, Himanthaliaceæ, Fucaceæ, Sargassaceæ.
  - B. Sperms with one flagellum; nonsexual spores nonmotile; reproductive organs external; with a regular alternation of sexual and nonsexual generations. Class, DICTYOTEÆ. 130 species. One Order, **Dictyotales.** Dictyotaceæ.

Phylum, RHODOPHYTA. Red Algæ.

I. Nonsexual reproduction by single thallus cells; trichogyne imperfectly developed; no pits between the thallus cells. Class, MONOSPORÆ. 50 species. One order, **Bangiales.** Bangiaceæ, Rhodochaetaceæ, Compsopogonaceæ.

II. Nonsexual reproduction by tetraspores usually developed in groups of four; trichogyne well developed; cells protoplasmically connected through large pits in the walls. Class, FLORIDEÆ. 3000 species.
  A. Sporophores ("gonimoblasts" or branches bearing the carpospores) of the sporocarp produced directly from the fertilized oogonium; mostly plants with filiform fronds. Fresh water or marine. **Nemalionales.** Lemaneaceæ, Helminthocladiaceæ, Chaetangiaceæ, Gelidiaceæ.
  B. Sporophores produced by auxiliary cells after these conjugate with the fertilized oogonia or their branching processes ("ooblastema").
    1. Sporophores produced by nearby auxiliary cells; marine plants.
      a. Sporophores produced by nearby auxiliary cells and growing outward in the plant body; filiform, foliaceous or massive plants. **Rhodymeniales.** Sphaerococcaceæ, Rhodymeniaceæ, Delessariaceæ, Bonnemaisoniaceæ, Rhodomelaceæ, Ceramiaceæ.
      b. Sporophores produced by the nearby auxiliary cells and branching copiously in the surrounding tissues of the plant body; fronds parenchymatous, flattened or leaf-like. **Gigartinales.** Acrotylaceæ, Gigartinaceæ, Rhodophyllidaceæ.
    2. Sporophores produced by remote auxiliary cells after these have conjugated with the branched "ooblastema" filaments arising from the fertilized oogonium; fronds filiform, branched, often flattened. Mostly marine, but a few fresh water species. **Cryptonemiales.** Gloiosiphoniaceæ, Grateloupiaceæ, Dumontiaceæ, Nemastomaceæ. Rhizophyllidaceæ, Squamariaceæ, Corallinaceæ.

Phylum, CHAROPHYTA. Stoneworts.

One class and one order, CHAREÆ. '160 species. **Charales.**

I. Crown of the oogonium with ten cells. Nitellaceæ.
II. Crown of the oogonium with five cells. Characeæ.

KEY TO THF ORDERS OF ALGÆ

1. Nonsexual fission algæ, unicellular, colonial or filamentous, blue-green or brownish, never with a pure chlorophyll-green color, usually with gelatinous walls; filaments often with heterocysts; never with cilia or flagella, but sometimes motile; chromotophores usually poorly defined. 2.
1. Mostly sexual algæ, but sometimes nonsexual, with a pure chlorophyll-green color or often red, purple, yellow, or brown; plants not propagating by fission; unicellular, colonial, filamentous, or massive; chloroplasts usually well defined; commonly with zoospores; some with silicious walls. 6.
2. With poorly differentiated nuclei, without a definite nuclear membrane, and with a low type of chromatophore. (CYANOPHYCEÆ). 3.
2. With well developed nuclei, with a nuclear membrane, and with highly differentiated chromatophores. (GLAUCOCYSTEÆ). **Glaucocystales.**
3. Not filamentous; unicellular or colonial, free or attached. **Chroococcales.**
3. Cells arranged in definite filaments. 4.
4. Filaments without hair-like tips, sometimes narrowed at the ends. 5.
4. Filaments with hair-like tips at one or both ends, with or without heterocysts. **Rivulariales.**
5. Without heterocysts. **Oscillatoriales.**
5. With heterocysts. **Nostocales.**
6. Cells covered with two silicious, usually ornamental valves, mostly brown or yellowish in color; unicellular, or simple filaments, sometimes on gelatinous stalks. (DIATOMEÆ). 7.
6. Cells not covered with two silicious valves. 8.

7. Valves without a raphe or pseudo-raphe; usually with a concentric or radiating symmetry around a central point, rarely isobilateral or zygomorphic; valve view usually circular; polygonal, or broadly elliptical in outline. **Eupodiscales.**

7. Valves with a raphe or pseudo-raphe, or with a sagittal line; with an isobilateral or zygomorphic symmetry, never centric; valve view mostly boat-shaped, needle-shaped, rod-shaped, or elliptic in outline. **Naviculales.**

8. Unicellular or simple free filaments, chlorophyll-green, with complex chromatophores containing prominent pyrenoids, reproduction usually by conjugation of the cell contents either through a conjugation tube or by the breaking open of the cell walls; cells and gametes never with cilia; unicellular forms usually of fantastic shapes, usually divided into two symmetrical halves. (CONJUGATÆ). 9.

8. Sexual process if present by typical isogametes, or heterogamous; plants commonly branched filaments or massive, the unicellular forms or simple filaments rarely corresponding to the above description. 10.

9. Thallus a filament or mostly unicellular, the cell wall usually divided into two symmetrical halves, cells mostly constricted at the middle; conjugation by the breaking open of the cell walls or by the formation of a primitive conjugation tube. **Desmidiales.**

9. Thallus a simple filament of cylindrical cells not constricted in the middle, but sometimes the contents divided into symmetrical halves; these latter forms distinguished from the preceding order by the definite filament and the prominent conjugation tube. **Zygnemales.**

10. Antheridia when present not consisting of a globular structure containing sperm-bearing filaments. 11.

10. Filamentous green algæ with globular antheridia containing sperm-bearing filaments, erect, branches in whorls; rhizoids thread-like; sperms biciliate, non-sexual spores absent; plants more or less incrusted with lime. (CHAREÆ). **Charales.**

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11. Plants green, rarely with a red or brown color and then unicellular; nearly all producing zoospores except the lowest; largely fresh water algæ, but some marine. 12.

11. Plants usually with the chlorophyll hidden by a brown, red, or purple pigment, always with a multicellular body, often massive; sperms motile or non-motile; mostly marine algæ. 29.

12. Plants unicellular or colonial, not truly filamentous. 13.

12. Plants filamentous or massive. 18.

13. Nonsexual unicellular or colonial algæ without zoospores, commonly with autospores or merely splitting apart; cells normally with one nucleus, not forming net-like or fantastic, radially symmetrical plate-like union colonies (AUTOSPORÆ). 14.

13. Isogamous or heterogamous sexual algæ usually with zoospores. 15.

14. Reproduction by autospores, the protoplast dividing within the mother cell and the daughter cells escaping singly or in colonies. **Selenastrales.**

14. Reproduction by vegetative division and separation by the splitting apart of the daughter cells. **Protococcales.**

15. Unicellular or colonial algæ with cells normally having one nucleus; the colonial forms not produced by the symmetrical aggregation of free zoospores. (CHLOROCOCCEÆ). 16.

15. Cenocytic algæ consisting of net-like or symmetrical plate-like colonies of peculiar form, produced by the definite arrangement and union of daughter cells in the parent cenocyte; (HYDRODICTYEÆ). **Hydrodictyales.**

16. Cells ciliated and active in the vegetative state; unicellular or in definite colonies, commonly spherical. **Volvocales.**

16. Cells not active in the vegetative stage. 17.

17. Vegetative cell division absent, cells separate or somewhat cenocytic. **Chlorococcales.**

17. Colonies increasing by vegetative division. **Tetrasporales.**

18. Cenocytic algæ, septate or nonseptate. 19.
18. Not cenocytic, but with normal cells having a single nucleus. (Conferveæ). 23.
19. Vegetative body usually septate, consisting of a series of cenocytes; chloroplasts forming a net, rarely in separate plates. (Siphonocladeæ). 20.
19. Vegetative body usually nonseptate, with distinct lenticular, oval, or plate-like chloroplasts. (Siphoneæ). 21.
20. Filaments branched; plants isogamous. **Cladophorales.**
20. Filaments unbranched, free-floating; plants heterogamous with stationary eggs. **Sphaeropleales.**
21. Isogamous, or sexual reproduction unknown. 22.
21. Sexual reproduction by highly specialized stationary eggs and motile spermatozoids; thallus tubular, branched or unbranched. **Vaucheriales.**
22. Small globular terrestrial plants with branched rhizoids penetrating the ground; zoospores with cilia of unequal lengths or with only one. **Botrydiales.**
22. Mostly large marine or sometimes endophytic algæ; zoospores if present otherwise. **Bryopsidales.**
23. Isogamous, or the free-swimming gametes of unequal size. 24.
23. Heterogamous, the egg stationary in the oogonium; oogonium developing a cortical layer after fertilization, or if not then certain cells of the filament with peculiar striate rings around the top. 28.
24. Thallus unbranched. 25.
24. Thallus filamentous, branched, usually abundantly so, the branches often with hair-like attenuated tips. **Chaetophorales.**
25. Chloroplasts reticulate, without pyrenoids; growing in fresh water. **Microsporales.**
25. Chloroplasts central or parietal, with one or more pyrenoids. 26.
26. Chloroplast single, central, stellate, with one pyrenoid; no zoospores known; aerial in habit. **Prasiolales.**
26. Chloroplasts parietal with one to many pyrenoids. 27.
27. Unbranched filaments; chloroplasts with one to many pyrenoids. **Ulotrichales.**
27. Thallus expanded, a 1-2-layered lamina or tube; chloroplast single with one pyrenoid; mostly marine plants. **Ulvales.**
28. Oogonium not developing a cortical layer after fertilization; zoospores with a crown of cilia; certain cells with striate rings at the upper end. **Oedogoniales.**
28. Oogonium with a trichogyne-like tip, covered after fertilization by a cortical layer; thallus disk-like or cushion-like; zoospores biciliate. **Coleochaetales.**

—29—

29. Mostly marine brown algæ; isogamous or with ciliated sperms, and large eggs, both gametes discharged from the gametangia; or with zoospores only. 30.
29. Mostly marine red algæ, with stationary eggs and non-ciliated sperms; mostly with tetraspores; zoospores absent; usually with cystocarps. 35.
30. Zoospores present; sexual reproduction by motile biciliate gametes produced in external gametangia; occasionally heterogamous, the extreme cases with non-motile eggs. (Phaeosporæ). 31.
30. Zoospores absent; sexual reproduction by means of motile sperms and non-motile eggs which are discharged from the oogonium; gametangia sunken or external; non-sexual reproduction absent or by means of nonmotile spores. 34.
31. Zoospores and isogametes similar and motile. 32.
31. Zoospores and heterogametes dissimilar. 33.
32. Frond various, simple or branched, but never differentiated with definite root-like and leaf-like parts. **Ectocarpales.**
32. Frond large, leather-like, usually stalked, differentiated with root-like and leaf-like parts; with zoospores only; plants usually very large. **Laminariales.**
33. Gametes large and small but both motile; plants medium to large, flat, branched, or orbicular, attached by rhizoids. **Cutleriales.**
33. Gametes a small active spermatozoid and a nonmotile egg; fronds filiform, tufted, attached by rhizoids. **Tilopteridales.**

34. Sperms biciliate; nonsexual spores absent; gametangia in sunken conceptacles; plants usually flat or flattish, branched, attached below, medium to large in size. (CYCLOSPORÆ). **Fucales.**
34. Sperms with one flagellum, nonsexual spores (tetraspores) nonmotile, reproductive organs external; fronds erect, flat, leaf-like, attached by rhizoids. (DICTYOTEÆ). **Dictyotales.**
35. Nonsexual reproduction by single thallus cells, monospores; trichogyne imperfectly developed; no pits between the thallus cells; plants red or purple, mostly filamentous or sometimes stratose. (MONOSPORÆ). **Bangiales.**
35. Nonsexual reproduction by tetraspores, usually developed in groups of four; trichogyne well developed; carpospores developed on filaments after fertilization; cells of the thallus protoplasmically connected through large pits in the cell walls. (FLORIDEÆ). 36.
36. Sporophores ("gonimoblasts" or branches bearing the carpospores) of the sporocarp on the sexual plant produced directly from the fertilized oogonium; mostly plants with a filiform frond; fresh water or marine. **Nemalionales.**
36. Sporophores produced by auxiliary cells after these conjugate with the fertilized oogonia or their branching processes ("ooblastema"). 37.
37. Sporophores of the sexual plant produced by nearby auxiliary cells; marine plants. 38.
37. Sporophores produced by remote auxiliary cells after these have conjugated with the branched "ooblastema" filaments arising from the fertilized oogonia; fronds filiform, branched, often flattened; mostly marine, but a few fresh water species. **Cryptonemiales.**
38. Sporophores produced by nearby auxiliary cells and growing outward in the plant body; filiform, foliaceous, or massive plants. **Rhodymeniales.**
38. Sporophores produced by nearby auxiliary cells and branching copiously in the surrounding tissues of the plant body; fronds parenchymarous, erect or spreading, branching, cylindrical, flattened, or leaflike. **Gigartinales.**

PHYLA, SUBPHYLA, CLASSES AND SUBCLASSES OF PLANTS.

A general table of the classification of the plant kingdom on a phyletic basis is given below. At present the writer recognizes 50 classes, a class being defined as a group of plants in a subkingdom or division whose members show an evident relationship. A class may also be defined as the largest, definitely determined, monophyletic group in a subkingdom. A phylum consists of one or more classes showing a probable relationship. It might be mentioned that a subkingdom is one of the seven progressive stages into which living plants may be divided, each stage being separated from the next higher by a more or less prominent hiatus.

Phylum I. SCHIZOPHYTA. Fission Plants.
  Class 1. Cyanophyceæ. Blue-green Algæ.
  Class 2. Glaucocysteæ. Higher Blue-green Algæ.
  Class 3. Schizomycetæ. Fission Fungi.
  Class 4. Myxoschizomycetæ. Slime Bacteria.

- Phylum II. Myxophyta. Slime Fungi.
  - Class 5. Plasmodiophoreæ. Clubroot Fungi.
  - Class 6. Acrasieæ.
  - Class 7. Myxomycetæ. Slime Molds.
    - Subclasses.
      - a. Ceratiomyxeæ.
      - b. Myxogasteræ.

- Phylum III. Zygophyta. Conjugate Algæ.
  - Class 8. Diatomeæ. Diatoms. (Subphylum A).
  - Class 9. Conjugatæ. Conjugates. (Subphylum B).

- Phylum IV. Gonidiophyta. Zoospore Plants.
  - Class 10. Autosporæ.
  - Class 11. Archemycetæ. Primitive Fungi.
  - Class 12. Chlorococceæ. Green-slimes.
  - Class 13. Hydrodictyeæ.
  - Class 14. Siphonocladeæ. Lower Tube Algæ.
  - Class 15. Siphoneæ. Higher Tube Algæ.
  - Class 16. Monoblepharideæ.
  - Class 17. Conferveæ. Confervas.

- Phylum V. Phaeophyta. Brown Algæ.
  - Class 18. Phaeosporæ. Kelps.
  - Class 19. Cyclosporæ. Rockweeds.
  - Class 20. Dictyoteæ.

- Phylum VI. Rhodophyta. Red Algæ.
  - Class 21. Monosporæ.
  - Class 22. Florideæ. Red Seaweeds.

- Phylum VII. Charophyta. Stoneworts.
  - Class 23. Chareæ.

- Phylum VIII. Mycophyta. True Fungi.
  - Subphylum A. **Phycomycetæ.** Algal Fungi.
    - Class 24. Zygomycetæ.
    - Class 25. Oomycetæ.
  - Subphylum B. **Mycomycetæ.** Higher Fungi.
    - Class 26. Ascomycetæ. Sack Fungi.
      - Subclasses.
        - a. Hemiascæ. Intermediate Sack Fungi.
        - b. Exoascæ.
        - c. Aspergilleæ. Tuber Fungi.
        - d. Discomycetæ. Disk Fungi.
        - e. Pyrenomycetæ. Black Fungi.
        - f. Deuteromycetæ. Imperfect Fungi.
    - Class 27. Laboulbenieæ. Beetle Fungi.
    - Class 28. Teliosporæ. Brand Fungi.
    - Class 29. Basidiomycetæ. Basidium Fungi.
      - Subclasses.
        - a. Protobasidiæ.
        - b. Hymenomycetæ.
        - c. Gasteromycetæ.

- Phylum IX. Bryophyta. Mossworts.
  - Class 30. Hepaticæ. Liverworts.
  - Class 31. Sphagneæ. Bog Mosses.
  - Class 32. Schizocarpæ. Granite Mosses.
  - Class 33. Musci. True Mosses.
  - Class 34. Anthocerotæ. Hornworts.

Phylum X. PTENOPHYTA. Fernworts.
- Class 35. Filices. Ferns.
  - Subclasses.
    - a. Eusporangiatæ. Primitive Ferns.
    - b. Leptosporangiatæ. Modern Ferns.
- Class 36. Hydropteridæ. Water-ferns.
- Class 37. Isoeteæ. Quillworts.

Phylum XI. CALAMOPHYTA. Calamite Plants.
- Class 38. Sphenophylleæ. (Fossil). Wedge-leaf Calamites.
- Class 39. Equiseteæ. Horsetails.
- Class 40. Calamariæ. (Fossil). Calamites.

Phylum XII. LEPIDOPHYTA. Scale-leaf Plants.
- Class 41. Lycopodieæ. Lycopods.
- Class 42. Selaginelleæ. Selaginellas.

Phylum XIII. CYCADOPHYTA. Cycad Plants.
- Class 43. Pteridospermæ (Fossil). Seed Ferns.
- Class 44. Cycadeæ. Cycads.
- Class 45. Cordaiteæ (Fossil). Cordaites.
- Class 46. Ginkgoæ. Maiden-hair-trees.

Phylum XIV. STROBILOPHYTA. Strobilus Plants.
- Class 47. Coniferæ. Conifers.
- Class 48. Gneteæ. Joint-firs.

Phylum XV. ANTHOPHYTA. Flowering Plants.
- Class 49. Monocotylæ. Monocotyls.
  - Subclasses.
    - a. Helobiæ.
    - b. Spadicifloræ.
    - c. Glumifloræ.
    - d. Liliifloræ.
- Class 50. Dicotylæ. Dicotyls.
  - Subclasses.
    - a. Thalamifloræ.
    - b. Centrospermæ.
    - c. Calycifloræ.
    - d. Amentiferæ.
    - e. Myrtifloræ.
    - f. Heteromeræ.
    - g. Tubifloræ.
    - h. Inferæ.

A NEW HYMENOPTEROUS PARASITE UPON ADULT BEETLES.

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The writer has recently received from Mr. W. V. Balduf, Assistant Entomologist of the Ohio Agricultural Experiment Station and graduate student at Ohio State University, specimens of an interesting parasite which appears to be new to science. This parasite is interesting not only because it attacks a well known garden pest, the cucumber beetle (*Diabrotica vittata*), but it is interesting also structurally and biologically.

The writer is indebted to Mr. Balduf for the following facts regarding its life history: The parasite attacks the adult beetle by mounting on the back of its host and thrusting its ovipositor into the thorax, apparently through one of the sutures near the base of the elytra, and depositing its egg within. The parasite larva feeds internally. In its earlier stages it has a sort of tail like terminal appendage which is lost before maturity. The mature larva escapes from the body of its host either at the junction of head and thorax or of the thorax and abdomen, and although the host is not outwardly defaced, it is killed. The parasite larva undergoes its transformation just below the surface of the soil in a closely woven silken cocoon. Pupation lasts approximately ten days. The parasite is not plentiful, having been found in an average of about one or two beetles per hundred late in the summer and somewhat more commonly in May and June.

In its mode of development the parasite reminds one of the common parasite of lady-bird beetles [*Dinocampus terminalis* Nees], but differs in many important details. It is perhaps more nearly like *Perilitus eleodis* Viereck, but here again there are marked differences in details, such as the manner and place of oviposition, the place of emergence from the host, and the method of pupation.

Following is a description of the adult female parasite:

Superfamily Ichneumonoidea.

Family Braconidæ.

Subfamily Liophroninæ.

Syrrhizus diabroticæ, new species.

This species does not fully agree with the characterization of the genus *Syrrhizus* Foerster, which is said to have the first cubital and first discoidal cells confluent and the notauli entirely effaced. In the present species the first abscissa of cubitus is only partially obsolete and the notauli are not completely effaced, being represented by a short groove at each lateral anterior angle and a deep dimple-like median fovea or depression near the posterior margin of the mesoscutum. It is apparently intermediate between *Syrrhizus* on the one hand and both *Centistes* Haliday and *Leiophron* Nees on the other, but agrees better with the former than with either of the latter. Considering the evident intergradation of the characters cited, it seems more reasonable to place it in *Syrrhizus* than to erect a new genus for it at this time.

Female.—Length 2.2 mm. Head viewed from above transverse, a little more than one and one-half times as broad as long, flattened in front and rounded behind, the occipital carina complete and far below the vertex; frons, vertex, occiput and posterior orbits smooth and polished; viewed from in front the head is very slightly broader than high, subtriangular in outline, convexly rounded above and subtruncate below; inner margins of the eyes nearly parallel, a little divergent below; malar space slightly shorter than the width of mandible at base; face hairy and shining, with a longitudinal swelling medially, and very finely and obscurely punctate laterad of the median ridge; antennæ inserted a little above the middle, 24-jointed, the basal joints approximately three times as long as broad, apical joints about twice as long as broad; mesoscutum perfectly smooth and polished, with the notauli effaced except for a short groove at each lateral anterior angle and a deep median fovea near the posterior margin; disk of scutellum smooth and small, with the transverse groove between it and the mesoscutum very broad and divided in the middle by a single longitudinal carina; lateral face of scutellum strongly rugose; metanotum longitudinally striate; propodeum rugulose except at anterior middle, with a median longitudinal carina on the anterior half and a distinct transverse carina extending completely across the sclerite a little behind the middle, the posterior face with several irregular longitudinal raised lines; spiracles small and round; mesopleura mostly smooth with the groove shallow and more or less weakly foveolate or rugulose; stigma of forewing broad; first abscissa of radius not half as long as the width of stigma, the second abscissa long and curved, not reaching to the wing apex; metacarpus a little longer than the anterior margin of stigma; basal half of first abscissa of cubitus effaced, the first cubital and first discoidal cells incompletely confluent; cubital vein beyond the intercubitus obsolescent; nervulus postfurcal by nearly its own length; first brachial cell narrowly open at its posterior outer angle; abdomen subequal to the thorax in length, curved downward at apex; first tergite increasing gradually in width from base to apex, longitudinally striate, about twice as broad at apex as at base and a little more than one and one-half times as long as broad at apex; second and following tergites perfectly smooth, the second large and occupying most of the dorsal length of abdomen, tergites beyond the second bent downward; ovipositor curved sharply downward and forward, the ovipositor sheaths broad, narrowed at base and apex and a little shorter than the length of first tergite.

Black; five or six basal joints of antennæ, mandibles, clypeus, palpi, and all legs including their coxæ pale reddish testaceous; face, prothorax and the mesopleura more or less reddish brown to piceous; tarsal claws, and antennæ except base of latter dark brown; wings hyaline, stigma and veins dark brown except medius and submedius which are pale; ovipositor testaceous, its sheaths black.

Male unknown.

Type locality.—Marietta, Ohio.

Type.—Cat. No. 25064, U. S. N. M.

Host.—*Diabrotica vittata* (Fabricius).

Type and three paratype females received from W. V. Balduf, of the Ohio Agricultural Experiment Station, by whom they were reared June 29 and July 2, 1921, from adults of the cucumber beetle.

DESCRIPTIONS OF ALASKAN DIPTERA OF THE FAMILY SYRPHIDÆ.

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All of the species treated in this paper except Sericomia cynocephala were collected by the Katmai Expeditions of the National Geographic Society. Full accounts of the insect collections of these expeditions are being prepared for publication, but as it is desired to refer to some of the species in other papers these descriptions are published in advance of the final report.

Chilosia platycera n. sp.

Male and female shining black. General form of the body elongate and rather slender. Vestiture of the body mostly pale, scutellum with a marginal row of slender black bristles, eyes naked, antennæ yellow, aristæ dark, naked; legs largely black, apex of each femur yellow, tibiæ and tarsi partially yellow; wings pale yellowish hyaline. Length 5-7 mm.

Female: Eyes bare, face and front shining black, front largely pale pilose, but with a few black hairs intermixed, face below the antennæ concave, facial tubercle rather prominent, much nearer the mouth than to the base of the antennæ. Antenna wholly yellow, arista dark, nearly black, bare, third segment unusually large, only slightly longer than wide. Thorax wholly shining black with short, pale, pile rather sparsely distributed. Scutellum with a few slender marginal bristles. Wings pale yellowish hyaline, halteres and squamæ pale, nearly white; legs in large part black, narrow apex of each femur, base and apex of each tibia and second, third and fourth tarsal segments on all the feet yellow. Abdomen shining black all over, pilosity short and pale grayish in color.

Male: Colored like the female, frontal triangle with long black pile, antennæ yellow, third segment decidedly smaller than in the female, pilosity of the body rather long and conspicuous, especially along the side margins of the abdomen, abdomen entirely shining, slenderer than in the other sex.

Female type, Katmai, Alaska, July, 1917. Allotype with the same data. Paratypes, 12 females and 3 males from the same locality taken in June and July, 1917, and one female from Savanosky, Naknek Lake, Alaska, July, 1919. Type in the Ohio State University Collection.

Chilosia robusta n. sp.

Male and female shining black and conspicuously pale pilose all over. Scutellum without bristles which are differentiated from the rather dense covering of pile. Eyes conspicuously long hairy; antenna yellow, arista dark colored, naked; wing yellowish hyaline, somewhat darker along the costa; legs largely black, tibiæ partly yellow. Vestiture over the whole body conspicuously pale yellowish in color, occasionally varying to golden especially in the female. Form robust. Length 9–12 mm.

Female: Front nearly as wide as either eye, shining black, pale pilose; face shining black concave below the antennæ, facial tubercle large and located somewhat nearer the oral margin than the base of the antennæ. Antenna yellow, first two segments partially brown, third segment about as long as broad. Femora black, yellow at extreme apex of each, tibiæ partially yellow, median third or more of each, brown to black, all the tarsi almost wholly dark colored with short golden pile beneath. Wing yellowish hyaline, darkest in costal region of basal half, veins brown, squamæ and halteres pale.

Male: Colored like the female except the body pile tends toward paler in the specimens studied. Abdomen entirely shining as in the female, and somewhat more slender than in that sex.

Differs from lasiopthalma as follows: The face is much less produced in both sexes making the distance between the base of the antennæ and the apex of the facial tubercle much shorter than in lasiopthalma, the pilosity of the eyes is paler and shorter and the wings are less infuscated.

Female type, Kodiak, Alaska, June, 1917. Allotype has the same data. Parotypes, five males and ten females with the same data as the type; seven males and fourteen females, Katmai, Alaska, July, 1917; five males and one female, Snug Harbor, Alaska, June, 1919.

Type in the Ohio State University Collection.

Syrphus attenuatus n. sp.

Male and female. Face yellow, without a black stripe, lower part of front including the insertion of the antennæ yellow, antenna largely reddish, third segment dark above, arista dark, eyes naked, occiput dark in ground color but largely hidden by a covering of yellowish gray pollen. Thorax dull blue black in ground color, scutellum rather bright yellow, entire thorax clothed rather densely with long yellow pile, wings hyaline, costal cells opaque yellowish; abdomen black with three pairs of spots and apex yellow, first pair of spots on second segment somewhat smaller than the other two pairs, triangular, with the long side anterior, outer angle produced over the abdominal margin, second pair of spots on the third segment, oblong, slightly concave anteriorly and convex posteriorly, outer angle very narrowly produced but scarcely reaching the lateral margin, third pair of spots on the fourth segment similar to those on the third, outer angle produced very narrowly over the margin, posterior margin of fourth segment, anterior and posterior margins of fifth segment and all of sixth segment, yellow. Length, 11 to 13 mm.

Female: Front black on the upper three-fourths, the lower half of the black color yellowish pollinose, less densely so at middle, front black pilose, pilosity continuing below the antennæ on either side next the eyes, much of the face sparsely yellow pilose; all the legs yellow to the bases of the femora, coxæ and trochanters dark, posterior feet pale brownish. All the abdominal spots much attenuated and reaching over the abdominal margins, fifth segment yellow with a curved black band about half the width of the segment.

Male: Vertical triangle black and black pilose, frontal triangle black on superior half and entirely black pilose, pilosity extending much below the antennæ at the sides next the eyes; cheeks blackish beneath the eyes, margin of the mouth behind yellow; legs to the basal fourth of the femora, black, otherwise yellow with the exception of the tibiæ which are partially brown, the hind ones nearly black. Fifth abdominal segment yellow with a very narrow median black marking. Genital segment all yellow.

Male type taken at Savonosky, Naknek Lake, Alaska, July, 1919. Allotype with the same data. Paratypes, ten males and seven females with the same data, a male from the same locality taken in August and a female from Katmai, Alaska, 1917. In the Ohio State University Collection.

The species varies somewhat. In some specimens the abdominal spots are larger and reach the lateral margins plainly and at greater width than in the type. In one specimen the narrow outer margin of the abdomen is all yellow and the black marking on the fifth abdominal segment varies in size and shape in different individuals. Sometimes the hind femora of the male practically entirely yellow. The pair of spots on the fourth abdominal segment is connected occasionally at the anterior inner corners, forming a band which is very deeply notched posteriorly. It is a large robust species, easily separated from others of its size by abdominal markings.

Syrphus curtus n. sp.

Male and female: Eyes naked, cheeks, mouth margin and facial stripe extending upward just over the tubercle, black; remainder of face yellow. Antenna largely black, only the inferior margin of the third segment reddish. Thorax yellow pilose, scutellum pale; wings hyaline. Abdomen with three pairs of yellow spots entirely separated from the margins of the segments, posterior margins of fourth and fifth segments and anterior outer corners of fifth segment also yellow. Length 8-9 millimeters.

Female: Front black on upper two-thirds, otherwise yellow with the exception of a narrow crescent shaped mark above each antenna which is dark brown, entirely black pilose. Yellow abdominal spots concave anteriorly and convex posteriorly making them somewhat kidney shaped with the outer anterior corner somewhat produced and pointed; the spots on the second segment are smaller and more transverse than the others with the inner ends evenly rounded; legs largely yellow, black to the basal fourth or fifth of the front and middle femora and to a greater extent on the hind femora. Hind tibiæ with dark areas and all the tarsi dark in part.

Male: Vertical triangle black, frontal triangle yellow with black pile. Abdominal spots similar to those of the female, but those on the third and fourth segments quite distinctly larger; legs colored similarly to those of the other sex but black of the femora more extensive, including nearly half of middle and front pairs and two-thirds or more of hind pair.

Female type, Savanoski, Naknek Lake, Alaska, August, 1919. Allotype with the same data. Parotypes, six males and one female from Savanoski, Naknek Lake, Alaska, 1919, and ten females from Katmai, Alaska, 1917. Type in the Ohio State University Collection.

The coloration of the legs is somewhat variable in the species, being darker in general in some specimens, and the black of the femora is more extensive in some specimens than others, especially is this true of the females. The extent of the black on the lower part of the front of the female varies somewhat and the dark crescent-shaped marking above the base of each antenna is more pronounced in some specimens than in others.

Syrphus limatus n. sp.

Male and female shining blue black, face with a wide, shining black stripe, wider than the yellow on either side of it, pointed above and reaching nearly to the base of the antennæ; cheeks shining black, eyes rather sparsely hairy, antennæ black, abdomen with three pairs of narrow spots, first pair small and located near the middle of the second abdominal segment and entirely separated from the margins, second pair near the anterior margin of the third segment very slightly oblique and extending toward the middorsal line but not quite reaching it, inner third of the spot somewhat widened and nearly touching the anterior margin, outer end reaching over the lateral margin in full width; third pair of spots similar to the second, but narrower, located near the anterior margin of the fourth segment; narrow posterior margins of fourth and fifth segments and anterior lateral corners of the fourth segment also yellow. Length 10–11 mm.

Female: Front shining black to the base of the antennæ, black pilose, with an irregular pollinose band reaching from eye to eye above the antennæ, this pollinose band is briefly interrupted at its middle. The yellow on each side of the face unites around the upper end of the black middle part and sends a projection up between the antennæ. Thorax shining black, scutellum dark brown; wing hyaline, stigma opaque black, space between first and second veins slightly infuscated back to the wing base; legs partly black, outer half of front and middle femora and apex of hind femur light brown; all tibiæ in large part brown, tarsi dark, nearly black.

Male: Very near to the female in size and coloration. The hind legs are more extensively black in this sex and the pilosity of the eyes is more pronounced.

Type in the Ohio State University Collection.

This species is somewhat like *creper* and *pauxillus.* It is larger than either and differs in having a much more extensive black marking on the face. The abdominal markings on the third and fourth segments extend over the lateral margins in which respect it agrees with venustus of Europe.

Sericomyia cynocephala n. sp.

Female: Face much produced, so that the distance from the base of the antennæ to the apex of the facial production is nearly twice the distance from the base of the antennæ to the vertex. Face uniformly yellow, lacking the black stripe commonly present in other members of the genus; cheeks from the anterior corner of the eye to the apex of the facial production shining black; front black, sparsely gray pollinose and black pilose; antenna black, third segment about as wide as long and very slightly reddish at base, arista black and long plumose; posterior orbits yellowish pilose. Thorax black in ground color, scutellum pale brown, whole thorax yellowish pilose; wing hyaline, veins mostly pale, stigma yellow, squamæ pale with a pale fringe, ballancers yellow; legs black, tips of femora, less pronounced on the hind pair, and bases of tibiæ yellow. Ground color of abdomen above and below black, segments two, three, and four above each with a pair of oblique elongate yellow spots. All of these spots are widened outwardly and none of them reach any of the margins of their respective segments; spots on the second segment widely interrupted, those on the other segments more narrowly interrupted. Length 14 millimeters.

Female type collected by V. Stefansson at Barrow, Alaska, spring of 1912. Type in the American Museum of Natural History.

This species is distinct from all the species of Sericomyia known to me by the extreme production of the face and the absence of the black facial stripe. In the other species of the genus I have studied the facial tubercle is pronounced, but in cynocephala this tubercle is only feebly indicated.

THE ZOOLOGICAL RECORD

1 Feb., 1922.

The Editor, Ohio Journal of Science:

Dear Sir: I should be glad if you would draw the attention of your readers to the present position of the Zoological Record.

Owing to the collapse of the International Catalogue of Scientific Literature in connection with which the Record was published from 1906 to 1914 the Zoological Society of London has undertaken to bear the whole financial responsibility for the preparation and printing of the Record.

Owing to the great increase of the cost of printing and to the very meagre support accorded to the Record by Zoologists and Zoological Institutes generally, the financial burden of this undertaking on the Zoological Society is becoming very severe. The cost of printing the Record now amounts to between 1500£ and 2000£ annually and the Society receives back by subscribers and sales less than 25% of this sum; I fear therefore, unless Zoologists are prepared to make greater efforts to support the undertaking, there is a strong possibility that the Council of the Zoological Society may refuse to find this large sum each year.

It appears therefore, to be the duty of every Zoologist to help so far as he is able to support this most invaluable work. All particulars and forms of subscription can be obtained from the Secretary of the Zoological Society, Regents Park, London N. W. 8., but I may mention that the price of the whole volume is now 2 pounds, 10 shillings and the price of the separate parts a proportional smaller sum.

Yours faithfully,

V. L. Sclater,
(Zoological Society of London).

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THE SEXUAL NATURE OF VEGETATIVE OR DICHOTOMOUS TWINS OF ARISÆMA.*

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While studying sex reversal in Arisæma triphyllum (L.) Torr., the writer accidentally came across some interesting examples of dichotomous twins which have a bearing on the theory of sex determination. Twin flower clusters were reported several years ago by Pickett† who discovered about a dozen of such plants. He says the two flower clusters were surrounded by two leaves, and also makes the casual remark that the two clusters "are of the same sex on each plant and are entirely independent, arising from two separate initial groups."

The twin shoots and separated twins must not be confused with the normal lateral buds, which are produced each season from the corm. The main corm often becomes smaller, not only from accidents to the aerial shoots and poor growing seasons which reduce the available food supply but also from excessive or vigorous lateral bud production. In case of dichotomy of the growing bud which results in twins, one can find all gradations from simple inflorescences with slightly flattened spadices ending in two tips and with a double-pointed spathe to individuals which have two entirely distinct aerial shoots, identical in appearance and situated closely side by side. Such pairs of twin shoots become entirely separated after a year or more because of the further development of the two buds and the dying off of the back end of the corm. The twins can often be recognized as such for several years after com-

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* Papers from the Department of Botany, The Ohio State University, No. 134.

† PICKETT, F. L. A Contribution to our Knowledge of Arisaema triphyllum. Mem. Torr. Bot. Club. 16:48. 1915.

plete separation, both because of their position in the ground, close together and with the buds pointing in the same direction, and because of the remarkable similarity of the vegetative characters and similarity in size. Occasionally there is a difference in size of the individuals, or in the length of the sterile tips of the spadices, or in the time of emergence from the ground. There is no reason why such differences should not be decided, since the original fission of the bud may be quite unequal. In the dichotomous branches of Vernonia baldwinii Torr. and V. altissima Nutt., for example, there is frequently a decided difference in the length and complexity of the two forks.* There might also be a difference in the more specific vegetative characters occasionally, for the same reason that the two sides of a symmetrically bilateral body may differ in the characters expressed as, for example, the differences in the details of venation of pairs of insect wings, differences in the lobings of the two halves of a leaf, differences in the colored spots of the heads of certain turtles which are usually symmetrical, and differences in the color of the eyes of dogs and men, where one occasionally finds individuals with one eye blue and the other brown. The same differences of expression must take place occasionally after separation of two bilateral halves of an egg or vegetative bud and it is, therefore, possible that identical twins may differ decidedly in very important characters.

Not only are the Arisæma twins, so far discovered, all remarkably alike in vegetative characters but they are of the same sex. Some are staminate pairs, some are carpellate, and some intermediate with both staminate and carpellate flowers on the spadix, just as is the case with normal individuals. But the most remarkable characteristic exhibited by the bisporangiate twins is that so far they have been identical or nearly identical in the distribution, position, and numbers of the staminate and carpellate flowers. Since the elaboration of the hypothesis of the Mendelian nature of sex, it has been supposed by some that the fact that identical or duplicate twins are apparently always of the same sex gave a very strong presumption in favor of the correctness of the chromosome-linked or Mendelian hypothesis. This is, however, not at all the case as will appear from the evidence given below, derived from a

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* Schaffner, John H. Unusual Dichotomous Branching in Vernonia. Ohio Jour. Sci. 19:487-490. 1919.

study of a considerable number of twins of Arisæma, when it is remembered that sex in Arisæma has nothing to do primarily with chromosome shiftings and can be controlled and reversed almost completely by environmental means.

CHARACTERIZATION OF TYPICAL EXAMPLES.

1. A plant with twin leaves on a common petiole and twin spadices on a common peduncle. The two leaves each had three leaflets and had short petioles coming from the common petiole. The spathe had two points and surrounded the two spadices. Both spadices were pure carpellate and the sterile tips both had the upper two-fifths colored dark purple.

2. Twin shoots coming from the same corm. They were alike in size and general appearance. Both had the sterile tip purple. Both had identical sexual expression, being monecious with a zone of carpellate flowers below. covering about three-fifths of the spadix, and with a staminate zone above. Both inflorescences had purple-red anthers and greenish white stigmas.

3. A pair of large twins with separate corms but evidently just recently divided—probably the preceding summer. Both were very late in coming out of the ground; both had green spathes and green sterile tips; and both were pure carpellate with violet stigmas.

4. A pair of small twins with distinct corms but still close together. Both had green spathes and green sterile tips. Both were pure carpellate. One plant was 8 in. tall and the other 7½ in.

5. Large separated twins, both 12 in. tall to the tip of the spathe. The spathes of both were a uniform dark purple at the tip on the inside, and purple and greenish-white striped below. The sterile tips of both were dark purple above, purple spotted in the middle part, and green below. The sterile narrow stalks of the sterile tips were both purple spotted. Both were pure carpellate with pale violet stigmas.

6. A pair of twins just separated and situated close together. Both were 6½ in. tall to the top of the sterile tip; both had one larger and one smaller leaf; both had the spathes striped above, broad purple stripes alternating with narrow greenish-white stripes, and uniform greenish-white below. Both had the

sterile parts of the spadices purple mottled at the tip, with a solid band of purple just above the middle, and with a slight purple spotting below, extending from the purple band to the base of the sterile stalks. Both inflorescences were carpellate on the main part of the spadix with purple stigmas; and on the stalks of the sterile tips, a little way above the carpellate inflorescence, both had four purple-anthered staminate flowers! There was a slight difference between the two inflorescences in that one had a small, additional staminate flower in the top of the carpellate part, in addition to the four staminate flowers further up.

7. A pair of separated twins with green sterile tips but with their short stalks above the flower-bearing part slightly purple mottled. The spathes had green tips with purple stripes on their sheaths below. Both plants were robust. One was 12 in. tall to the top of the sterile spadix and the other was 11 in. Both were pure carpellate.

8. A pair of twins still united on the same corm. They were remarkably alike but one was slightly taller than the other, measuring 7½ in. while the other measured 7¼ in. Both had the sterile spadices or tips expanding decidedly toward the base. The tips were purple mottled while the bases were pure green. The spathes were greenish on the outside; but each had a broad band of purple on the inner side, one on the right side and the other on the left . The opposite sides of the spathes had a narrower purple mottled band, while the center of each was green slightly mottled with purple. The spathes, therefore, showed a decided right and left symmetry. The sheaths of the spathes were both folded clockwise, but this is a fluctuating character. Both inflorescences were pure staminate.

9. A pair of twins which developed in the writers experimental plots. The original plant was a pure carpellate individual brought in from the woods with others for experiments on sex reversal. This individual was treated for reversal to the male state by having its root system and leaves greatly reduced and being kept in a comparatively dry condition. The following year the growing bud showed that dichotomy had taken place, as the corm developed twin shoots. Both branches were pure staminate, being completely reversed in sex, along with a similar change in most of the other individuals in the plot that had been treated in the same way. The twins were of equal size and

character and developed at the same time. The plot containing the twins was then treated for reversal to the female state by an application of rich cow manure and abundant water supply during the entire spring and summer. The following spring (1921) the twins had both reversed their sex completely and were now pure carpellate again. Examination of the underground parts showed that the corms had separated, although with the dead part still united. The twins were now of unequal size and one was nearly a week earlier in coming out of the ground than the other.

Arisæma dracontium (L.) Schott.

Some observations and experiments were also made on the green-dragon. This species consists of normal monecious and staminate individuals with occasional abnormal intermediates.

10. A plant with dichotomous inflorescens. The spathe ended in two separate points, the free points being one inch long. The spadix was double but united except near the tips of the sterile part. The entire double spadix was staminate. One of the free sterile tips was five-eighths inch long and the other seven-eighths inch. There was also some difference in thickness.

11. A simple staminate plant was transplanted from the woods with others in 1920 and treated for continuation of the staminate condition. In 1921 it gave rise by dichotomy to identical staminate twins.

12. A pair of tall, robust twins that looked like monecious individuals, but both stalks were completely sterile, each having a small, abortive structure where the inflorescencs should have developed. They were still united on a single very large corm. This corm was transferred to the experimental plots in 1920 and treated for reversal to the staminate condition by reducing the root system and leaf surface decidedly. In the spring of 1921 both came up as pure staminate shoots. One came out of the ground a week earlier than the other.

CONCLUSIONS.

All of the twin Arisæmas described above showed a remarkable similarity in vegetative characters and were exactly alike in sexual expression. Since it has been established that the sexual state of Arisæma can be changed at will by proper treatment,* it becomes evident that *identity of sex in duplicate twins can not be regarded as giving any conclusive evidence in support of the hypothesis that sex is determined by Mendelian factors.* As shown in the examples of twins described above in Numbers 9 and 12, the sex of twins has been completely reversed and the reversal was identical for each twin of a pair. The intermediate examples are even more striking than those with pure sexual expression. Cases like the one described under Number 6 must certainly be regarded as most remarkable in view of the fact that the sex of the individual is so easily changed. All these cases show that the nutritive balance or whatever it is that determines the sexual state must act with decided precision when individuals of like heredity develop under like conditions. Although so far the writer has no evidence that Arisæma twins placed in different environments would develop the opposite sexual states in any given season, yet, in view of the fact that any ordinary individual can be changed from season to season and that the pairs of twins have actually reversed their sex to the opposite state in agreement with a change in nutritive environment, it appears that such must be the case.

As shown by the examples listed above, certain pairs of dichotomous twins show fluctuation of a considerable degree, but so far this has been found mainly for size, folding of the spathe, emergence from the ground, and the like. The varietal characters, like coloring of the spadix and spathe, shape of the sterile spadix and length of its stalk, shape of leaflets, color of anthers and stigmas, etc., are remarkably alike in each pair and deviate only in minute detail.

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* SCHAFFNER, JOHN H. Control of the Sexual State in Arisaema triphyllum and Arisaema dracontium. Am. Jour. Bot. 9: 72-78. 1922.

EMERGENCE OF A MAYFLY FROM ITS NYMPHAL SKIN.*

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The emergence of a subimago mayfly from its nymphal skin observed by Superintendent George F. Miller and Captain Bickford, both of the Ohio State Fish Hatchery at Put-in-Bay, Ohio, and later described to me by them, impressed me as being of sufficient interest to warrant the addition of one more account to the number that have already been published regarding the subject of mayfly emergence.

The transformation occurred in a large, portable fish tank which had been standing for a number of weeks on the dock in front of the Hatchery building. This tank had been filled with water from the lake by means of a steam pump which had its intake lying very near the bottom and, presumably, the mayfly nymph had been drawn up with the water. Mr. Miller and Captain Bickford were standing at the side of the tank and were thus in an unusually fortunate position for observing the entire process of emergence. It occurred sometime during the month of June. The nymph swam upward from the bottom of the tank and when it reached a point about six inches beneath the surface of the water the nymphal skin split along its dorsal surface and the subimago began to push out. By the time it had reached the surface the subimago had freed itself entirely from the nymphal skin and was able to fly away immediately.

Neither of the men was familiar with the names of ephemerid species or the criteria for distinguishing them and therefore it is impossible to say to which one this individual belonged. The species which occur most commonly in the region of Put-in-Bay during the late spring and early summer are Hexagenia bilineata and Ephemera simulans.

Needham ('18) describes the emergence of *Hexagenia bilineata* as follows: "Transformation occurs at the surface

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* Papers from the Lake Laboratory, Ohio State University, No. 74.

of the water and usually at night. The grown nymph swims up and floats. A rent appears in the skin of its back. The subimago suddenly emerges from this rent, its wings expanding almost full size instantly. It stands a moment on the surface and then rises and flies away to the shore." Heptagenia was seen emerging under laboratory conditions by Clemens. He says, "they were observed to crawl up sticks placed in the breeding jar for the purpose and transform just above the water-level."

Some species are apparently able to adapt themselves to varying conditions, as is shown by their ability either to crawl up some solid support or else arise directly from the surface of the water. This is the case in *Chirotenetes albomanicatus* as described by Miss Morgan. She writes: "They crawl up on the shore, leaving their cast skins clinging to the stones or less often they flew up directly from the mid-current." Needham's ('05) statement regarding the same species: "Transformation takes place at the surface of the water as in other species," was made some years before Miss Morgan published her observations. It is merely an example of the fact that our knowledge of habits is subject to modification and it leaves open the possibility that the case I have described may concern some species for which other descriptions have been given, perhaps a Hexagenia or a Heptagenia.

Of the various accounts concerning emergence given in the literature, a description by Miss Morgan for *Iron fragilis* (Heptageninæ) appears to resemble the instance reported to me most closely, so far as the ability to fly immediately upon emerging from the water is concerned. I do not mean to imply any identity of species. Miss Morgan says, "The nymphs popped from the surface of the water and flew unsteadily upward. * * * " She was probably not in a situation which enabled her to describe what occurred before this, but presumably some preliminary processes took place beneath the surface. Another account which bears some resemblance to the one I have given is by W. E. Howard and concerns *Polymitarcys albus*. "I have seen the subimagos emerge and arise from the surface of the water in great numbers, but always just far enough from shore so that the nymph skins were immediately swept into the current. * * * " Somewhat similar to this is Needham's description of the emergence of *Caenis diminuta.* "It emerges from the water at nightfall leaving its nymphal skin floating on the surface, and, alighting on the first support that offers, sheds its skin again. * * * "

In neither of the last two accounts is it definitely stated whether the mayfly issued from its nymphal skin after reaching the surface of the water or whether the process began before that. In the case of *Iron fragilis* with regard to which Miss Morgan uses the phrase, "popped from the surface of the water," it would appear that the shedding of the nymphal skin must have occurred beneath the surface. The emergence I have described, is, I believe, the only case on record in which such a process has actually been observed.

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A NEW TYPE OF BRYOZOAN GIZZARD, WITH REMARKS ON THE GENUS BUSKIA.

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A certain few of the Ctenostome Bryozoa have long been known to possess a gizzard or grinding organ at the cardiac end of the stomach, though such information may be sought for in vain in nearly all text books dealing with the group.

This structure is best known in the genus *Bowerbankia* Farre, owing to the work of Hincks (1880, text figure on p. xxiii and discussion on pp. xxiv-xxvii), and especially to the excellent histological description by Calvet (1900, p. 227–230, 232–234, Pl. VI, Fig. 13 and Pl. VII, Fig. 4).

Davenport (1891, p. 63) incorrectly homologizes the gizzard with the lower end of the chilostome œsophagus. Calvet (1900, p. 233) is undoubtedly correct in stating that it is the cardiac end of the stomach which is thus modified.

The genera *Amathia* Lamouroux, *Vesicularia* Thompson and *Avenella* Dalyell also possess a gizzard similar to that of *Bowerbankia*. All of these genera belong to the family Vesiculariidæ.

In the foregoing genera the gizzard has the appearance of a rounded distension of the cardiac end of the stomach, or, to quote Calvet (p. 228), "la forme d'une sphere tronquee aux deux poles." The epithelial lining of the gizzard consists of enlarged and elongated cells which are easily visible under the ordinary low power of the microscope. The walls of these cells at their inner free ends are heavily chitinized, so that each cell thus presents a separate pointed chitinous tooth for the trituration of the food, (see Fig. 8). The bryozoan gizzard as thus described is unique in its armature.

A strong layer of circular muscles completes the grinding apparatus, which operates by rhythmic contraction and relaxation. Hincks (1880, p. xxvii) states that he has seen the food, after passing through the gizzard, driven back into it by a retrostaltic movement of the stomach and again submitted to its action.

The new type of gizzard to be described has been discovered in another family of the Ctenostomata, the Buskiidæ, of which the genus *Buskia* Alder is the only representative. Alder (1856, p. 156) failed to note the presence of a gizzard in *B. nitens* and Hincks (1880, p. 532) also failed to discover it. Later Hincks (1887, p. 127) described *B. setigera* from the Mergui Archipelago, again failing to note the presence of a gizzard. The small size of the individual in *Buskia* (in *B. armata* the length is .6 mm. and the breadth .2 mm.) and the much smaller size of the gizzard in comparison with that in the Vesiculariidæ, together with the fact that it is divided into lobes, are responsible, no doubt, for this failure to find it.

In 1912 Osburn (p. 256) re-described Verrill's *Vesicularia armata* under the name *Hippuraria armata* (Verrill). In his original description Verrill (Verrill and Smith, 1874, p. 710) had not noticed the gizzard in this species. Osburn figured and described the gizzard for the first time (p. 256, Pl. XXIX, Figs. 84a and 84b). See Figures 1 and 2.

More recently Harmer (1915, pp. 85–89) has restudied the genus *Buskia* and has found a gizzard in *B. nitens* and *B. setigera*. If his figures (Pl. 5, Figs. 10, 15 and 16), which are small and not detailed, are to be relied on, the gizzard in these species is of the same type as in the *armata* of Verrill. Harmer indicates that *armata* belongs to the genus *Buskia* and is closely related to *B. setigera*, a conclusion with which we are quite ready to agree. There is reason for considering it a distinct species, however, for *armata*, as far as observed, does not possess basal spines for the firmer attachment of the zooecium and the zooecial wall is not perfectly transparent as described by Hincks, but is of a yellowish horn color. *Buskia armata* should be kept separate for the present at least, especially since its distribution in the North Atlantic lies to the northward and it tends to disappear toward the tropics.

Osburn's description of the gizzard (1912, p. 256) is as follows: "a small but distinct gizzard, not completely surrounding the gut, but forming several rounded lobes, with pointed teeth projecting into the cavity." The four lobes of the gizzard, with a band of circular muscles, is shown by Osburn in Plate XXIX, Figs. 84a and 84b.

The nature of the gizzard lobes and their mode of formation have been worked out by the junior author. The grinding structure consists of four mamillate, or low, rounded-conical structures, which are heavily chitinized, provided with pointed chitinous teeth of varying length and thickness and which are continuous with the chitinous cone. The arrangement of these cones, with their bases directed outward, gives a somewhat squared outline to the gizzard in cross-section, as shown in Pl. I, Fig. 3. The rounded surfaces, with the teeth projecting into the lumen of the digestive tract, practically close the cavity when the gizzard muscles are contracted, and the teeth are interdigitated when in this position. In operation in the living specimen, the gizzard lobes are seen to separate for some distance and then to close strongly and sharply together.

While in *Bowerbankia* and related genera each epithelial cell of the gizzard is chitinized on its grinding surface (see Fig. 8), thus making as many teeth as there are cells, in *Buskia* this is not the case. The hollow concavity of the chitinous cone is filled with elongated epithelial cells, those nearest the center being the longest. Together these cells secrete the chitinous lobe as one continuous structure, the teeth also being a part of the mass (Figures 3 to 7).

With its band of muscles, the entire gizzard in *Buskia armata* measures only about .075 mm. in diameter. Each cone measures about .0414 across the base and about .0234 in height. The teeth are quite variable in size but average about .007 mm. in height. Each cone bears about 30 teeth, though often the number is much less than this, and the teeth at the tip of the cone are larger and stronger than those farther down on the side. The layer of chitin is about .002 mm. in thickness, when fully developed, but thins out somewhat toward the base and then suddenly becomes thickened at the margin to form a ring about the base. The teeth are conical and hollow at the base and the chitin forming them is somewhat thicker than that of the cone on which they are borne. These relations are well shown in Figures 3 to 7.

Much variation is shown in both sections and total mounts in the exact form of the chitinous cones, possibly depending somewhat upon the amount of chitinization. Sometimes the lobes are almost hemispherical and seem to lack the rim around the base. As such structures appear thinner and lighter in color, it is probable that they have not reached their full development. The teeth also vary much in form, size, number and the angle at which they project.

The difference in the structure of the gizzard affords additional evidence for the separation of the family Buskiidæ from Vesiculariidæ, the other family in which a gizzard is known to occur. That *Buskia* represents a higher specialization in the formation of a grinding organ can scarcely be doubted. There are other evidences of a more highly specialized condition in the greatly elongated and spiral arrangement of the bristles supporting the collar and in the mode of branching, (see Fig. 1). The presence of a lateral membranous area also marks this family off sharply from the Vesiculariidæ.

Buskia armata (Verrill) is the only species thus far recorded from the Atlantic coast of North America. Its known distribution is from Massachusetts Bay to Beaufort, North Carolina. On the southern New England coast it grows profusely, spreading over hydroids, algæ, etc. In this region it often rises in free branches more than an inch in height, but toward the limits of its range only the creeping adherent stage is seen.

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EXPLANATION OF PLATE.

Figures 1 and 2 are from Osburn's Bryozoa of the Woods Hole Region. Figure 8 is modified from Calvet, Bryozoaires Ectoproctes Marins. Other figures by the junior author.

Fig. 1. An individual of *B. armata* (Verrill), the zooid retracted. The gizzard is shown in partial side view (at G) and the spiral bristles of the collar (at B).

Fig. 2. Complete intestinal tract, showing the oesophagus (O), gizzard (G), stomach (S) and intestine (I).

Fig. 3. Diagrammatic cross-section of gizzard showing circular muscles (M), epithelium (E) and chitinous cone (C) with teeth.

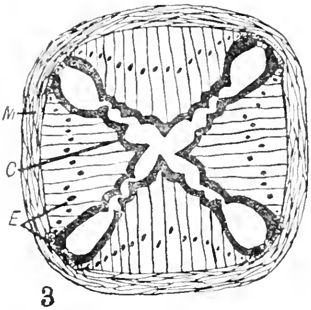
Fig. 4. Diagrammatic side view of a cone showing the arrangement of the teeth and the thickened rim around the base.

Figs. 5, 6 and 7. Camera lucida drawings of actual cross-sections of different cones. Some of the differences in form may be due to the fact that they are not cut quite in the same direction.

Fig. 8. Cross-section of the gizzard of *Bowerbankia* for comparison. Note that here each epithelial cell bears its own chitinous tooth. The enlargement is much less in this figure than in the others.

A New Type of Bryozoan Gizzard,
R. C. Osburn and Ruth M. Veth.

PLATE I.



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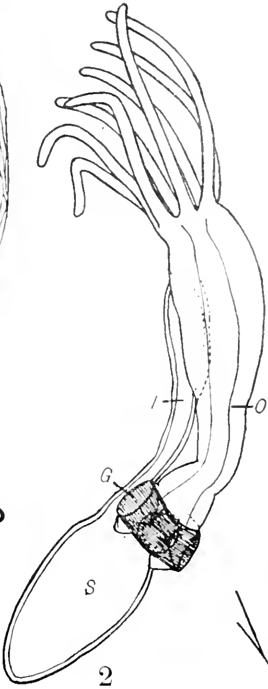

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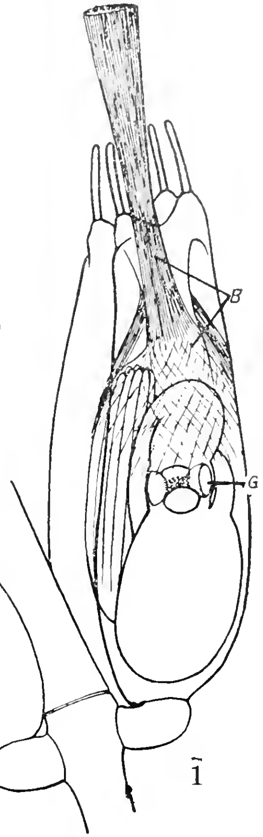

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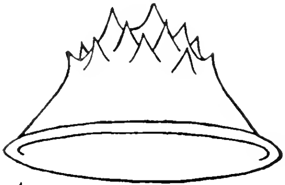

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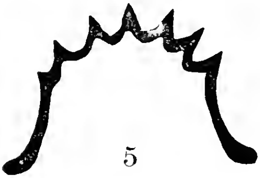

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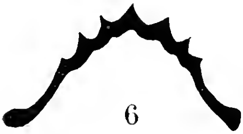

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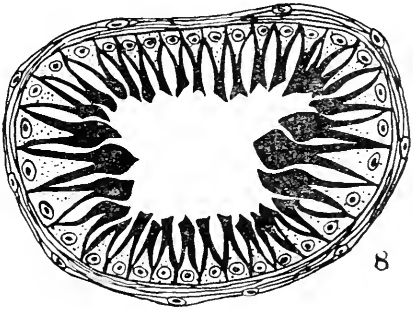

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HABITS OF THE COMMON MOLE.*

Scalopus aquaticus machrinus, (Rafinesque).

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In the United States there are five genera of moles, Scalopus, Parascalops, and Condylura appear in the eastern portion; Scapanus and Neurotrichus are found west of the Rockies. Of these genera, Scalopus is most widely distributed and consequently best known and most divided into species and sub-species. Jackson, in "A Review of the American Moles," has thirteen varieties of Scalopus listed and described along with their geographical distribution. His work on moles is notable and his analytical key gives an easy means of identifying varieties, doing away with much of the confusion arising from the same variety of mole appearing in various localities under as many as twenty different names, the genera being confused as well as the species.

The mole upon which this paper is based is *Scalopus aquaticus machrinus* (Rafinesque). The observations regarding it will deal primarily with those points to which other writers have given little or no attention, or points upon which I have found conflicting statements.

Moles are often said to be entirely insectivorous. This statement, no doubt, is based upon dentition study, for the study of the stomach contents will soon prove that moles are rather omnivorous. It is commonly known that a large percent of their food is made up of earthworms which they detect in the soil through the use of the tactile hairs and the sensitive nose. I have noticed that the motion of a wriggling worm along the side of a mole will cause the latter to turn quickly and press the worm down with the front feet and the head. The mole then waits for further activity on the part of the worm, apparently depending upon this to show just where it is. If there is no further activity the mole turns its nose about in an effort to locate the worm, presumably using the sense of

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* Part of a thesis offered in partial fulfillment of the requirements for the degree of Master of Arts from Ohio State University.

smell under these conditions. The nose is usually in motion, but it is my belief that it is through a sense of touch rather than through a sense of smell that the nose is most useful in food getting when the food taken is alive and has the power of motion.

I have found their method of eating earthworms interesting. Small worms like *Helodrilus foetidus* (Savigny) and *Helodrilus caliginosus* (Savigny) are eaten entire, but larger worms like *Lumbricus terrestris* (Linnaeus) are torn to pieces with the claws. A mole may work several minutes upon a large worm, tearing it into strips and short sections, rolling it about with the front feet and the mouth, thus getting the parts of the worm almost free from the ingested earth before eating them.

Whenever I have offered captive moles any of the insects or insect larvæ commonly found in the soil, they ate them greedily. Beetle larvæ, ants, maimed flies, and small crustacea were all eaten. Large beetles such as Lachnosterna and Lucanus were also eaten, but the wing covers and hard parts of the exoskeleton were generally refused. Prof. E. L. Mosley has found that captive moles refuse wooly insect larvæ, adult Colorado potato beetles and their larvæ. Analysis of stomachs of moles show a preponderance of earth worms, a large percentage of larvæ of Lachnosterna in season, various Carabidæ, and insect larvæ of different sorts. The most noticeable insect larvæ were those of the Elateridæ, no doubt due to the fact that their tough bodies resist mastication more than the soft bodies of other insect larvæ. In the stomachs were also found insect pupæ, earthworm egg cases, grains of oats, corn and grass. One mole taken from a clover field in December had 95% of the stomach contents made up of small ants, and since the ants were all of one species, this indicates that moles are given to plundering ant hills.

Grass found in the stomach was at first thought to have been introduced accidentally until a captive mole was found to eat grass, making as high as one-fourth of a meal upon fresh lawn clippings. This led to further experiments with wild and captive moles to find out what vegetable food they might take. It was shown, to the author's satisfaction at least, that moles are guilty in some cases of eating sprouted corn and in rare instances of eating roots and tubers. Moles in captivity, when short of water, ate Irish potatoes regularly, and would eat freely of apples, apple being taken by some moles very shortly after they had been captured. None ever ate sweet potatoes or parsnips. One ate only sparingly of carrots. The study of marks upon partially eaten Irish potatoes has led some to say that moles could not have made them, but that they were made by mice. My observations of captive moles show that marks resembling tooth marks of mice are made by moles, both by the teeth and the claws of the front feet.

Moles in captivity will eat soaked corn readily and will live for several days upon this diet alone. When this diet has been supplemented with apples and earthworms three or four times a week I have succeeded in keeping moles alive for as long as forty-one days. Soaked wheat and oats are not as readily eaten as is soaked corn. It seems that when a mole burrows unerringly along a corn row, he not only follows the line of least resistance through the soil, provided by the mark of the planter shoe, but he also eats some of the corn along with other food found. Whether the corn is eaten or not, the young plants usually die from having their root systems torn to pieces.

Moles will usually take meat when captive, eating lean beef, fish, fresh or salted pork, mice, frogs, and even small snakes. They have no trouble in disposing of live mice such as *Microtus pennsylvanicus* (Ord) this fact making the theory that potato tubers are eaten by mice that follow along the runways of moles very untenable. In eating furry animals the mole discards most of the hair and skin, also some of the larger bones. The hind feet and strips of skin are all that are usually left after a meal upon a meadow mouse.

The mole does not ordinarily drink. I observed only one captive mole drink, taking water by lapping. In dry summer months moles may be found far from water and in such situation must depend upon the water found in their food. It would be of interest to observe moles in dry weather when earth worms are scarce or excessively deep, to see if it is then that depredations in potato patches occur. Observations upon captive specimens indicate that plant roots and tubers are eaten chiefly to satisfy thirst.

Curiously enough, no reference is made by most authors to the swimming habits of moles. Some state that the mole can undoubtedly swim, and one author has given the mole great powers of swimming, due to powerful strokes of the great front feet. *Scalopus aquaticus machrinus* (Rafinesque.) does swim well, but the front feet play no part in propelling the animal, they are used only in turning or in righting when not on an even keel. The front feet are held together under the chin where they cut the water like the prow of a tiny motor boat, the propeller in this strange craft being the webbed hind feet which alternate with each other in their movements. The flexible nose is held curved upwards, raising the nostrils well above the water. I have used a stop-watch upon swimming moles and find that the swimming rate averages about a foot per second. I have found the maximum speed in running to be only a little more than double the swimming rate, averaging 26.7 inches per second in the specimens tested. Both of these speeds are low, the small hind feet being poorly adapted for swimming and the large front legs so wonderfully adapted to a strong side thrust in digging are poorly adapted to running.

Moles usually bear a few external parasites, such as fleas and mites, and numerous internal parasites. Nematode worms are not uncommon in the stomach. The most common internal parasite is *Moniliformis moniliformis* (Travassos). The intestines are sometimes so clogged with these parasites that one wonders how food is able to pass along the tract. Moles containing as many as three dozen of these worms give no evidence of the fact in any way unless it be in their ravenous appetites. They must have no difficulty in supplying both themselves and their parasites with food, for even the most heavily infested moles that I observed were in good condition and seemed to have as much fatty tissue as moles not infested. Of twenty moles taken in August, 1917, the average for stomach worms was 1.2 and for intestinal worms 16.4 per animal. The intestinal worms of one animal numbered 23, their average thickness 1.4 mm. and their total length 333.5 cm. The length of the intestine of the mole was 115 cm., making the length of the enclosed parasites nearly three times the length of the intestine that held them.

The genus *Moniliformis* is placed in the subfamily *Gigantorhynchinæ* (Travassos, 1915) this being a subfamily of the *Gigantorhynchidæ* (Hamann, 1892). The members of this genus are parasites in the intestines of rodents. As far as I know the mole has never been included in the list of hosts of this genus of Echinorynchs. If this be true it is not surprising, for I find that moles of one collecting ground may be heavily infested with the parasites, while moles a few miles away may be entirely free from them.

On account of their tunneling in lawns, flower gardens, truck patches, golf links and such places, the mole is commonly regarded as a pest. From the standpoint of his food, he is to be considered beneficial, but when a mole uproots hill after hill of melons to get the larvæ of the striped cucumber beetle projecting from the roots of the vines, the cure is decidedly worse than the disease. Once the mole finds a good feeding ground he can not be easily driven away, and if he is doing any real damage it will be found advisable to destroy the animal in some way rather than to attempt to make him seek other feeding grounds.

Experiments made by placing salt, sulphur, pepper and other irritating substances in mole runs in an attempt to drive them out of lawns and golf links have proven failures, the animal simply building another set of tunnels in another part of the lawn or golf course. One often hears that castor bean plants about a garden will keep moles away, but the writer has seen moles burrow directly under castor bean plants. Dogs can be trained to catch moles, but they will not eat them, presumably on account of their bad odor. Cats also catch moles, usually at night, they also refusing to eat the captured animal. Poisoning is one of the artificial means that may be used in reducing the number of moles, the most convenient method consisting of soaking corn, then placing strychnine or arsenic in the heart of the grain by pricking it in with a toothpick or other blunt instrument. The poisoned bait should be placed in the mole runways, one grain of this being sufficient to kill a mole. Care should be taken to select no poison with a decided odor, as this will lessen the efficiency of the method. I have found arsenic the most satisfactory poison to use.

The most common means of destruction, also the most efficient, is the use of traps. Traps of the nature of pitfalls have proven useless in the hands of the author, yet if they are carefully set they occasionally make a catch. Moles are often found drowned in wells walled up with boulders, but in this case it is probably thirst that causes the mole to lose his life in this manner. Of the various spring traps set in runways, one is of equal value with another if properly set, but on account of the use to which the skins may be put, the harpoon type of trap is the least desirable.

Scalopus aquaticus machrinus (Rafinesque.) will likely continue to be an animal small in numbers among us on account of its breeding habits, for it breeds only in early spring of each year and the number at birth is small, averaging four or five. On account of its food habits and its depredations in lawns and cultivated fields, it will always be of economic value, and of special scientific interest on account of its subterranean habits and high degree of specialization.

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A CASE OF UNHINDERED GROWTH OF THE INCISOR TEETH OF THE WOODCHUCK.

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Late in the fall of 1921, long after the normal woodchucks had gone into retirement for the winter the groundhog whose head is shown herewith was caught near Oxford in a trap set for skunks. The trapper killed the woodchuck with a club, breaking two of the teeth in the process, one of which he picked up. The pelt being valueless he cut off the peculiar looking head and threw the body away making the observation that the animal was much undersized and excessively thin.

The head was brought in, mounted by a local taxidermist, and put upon exhibition in an office window. I take this opportunity to thank the exhibitor, Mr. Chas. Wright, for permission to photograph the mount.

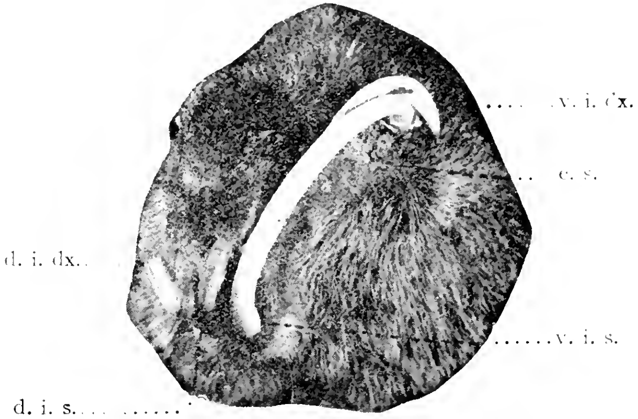
There is no evidence as to what happened to deform the animals, but the results are clear. In some way the incisor teeth of the woodchuck's lower jaw became deflected to the animal's left side and the incisors of the upper jaw turned enough to the right so that the two sets passed each other and no longer could be kept worn down by gnawing.

The left lower incisor grew in a regular curve up to the eye, ploughed through the eye and blinded it. It can be seen that the direction of growth was changed into a section of a larger circle as the end of the tooth slid backward along the frontal bone. The continuous curving growth of the tooth was not to be resisted by bone, however, and so the point of the tooth perforated the skull a short distance behind the eye socket and is said by the preparator to have penetrated the brain also.

This perforation of the skull and brain must have been some time before the animal's death, for the last visible part of the tooth is sheathed with a connective tissue envelop probably continuous with the periosteum of the skull through which the tooth passed. How far into the brain the tooth penetrated can never be determined. The whole socket of the eye was a suppurating mass when the animal was killed.

The right lower incisor was crowded between the left lower incisor and the bones of the left side of the face. It shows the effect of pressure and also that it was rubbed between its mate and the skin of the face. The hair on the face is worn very close along the line of this tooth also. Unfortunately since it was broken across when the animal was killed, no more accurate information can be had as to its position. The photograph shows it ending freely over the part of the left lower tooth which disappears into the head.

The stump of the right upper incisor is shown on the animal's right. The tooth is curving sharply and if the part broken off could be found it might show that the point was nearly as high as those of the teeth on the lower jaw.



d. i. dx.—Right upper incisor (broken off).
d. i. s.—Left upper incisor which passes down the animal's throat.
e. s.—Left eye socket through which the lower incisor plowed.
v. i. dx.—Right lower incisor (broken off but placed about as it must have been in life).
v. i. s.—Left lower incisor penetrating the skull and brain.

The left upper incisor turns directly down and back into the mouth and, according to the man who mounted the head, extended down the throat for more than an inch.

This case is a fine example of the way rodent chisel teeth with persistent pulps (or with continuous growing germs) act when for any reason the wearing of the teeth is hindered. The fate that follows is inexorable and starvation is its logical end.

How did the animal get any nourishment at all? The bodies of the upper and lower incisors firmly fixed side by side seem to make entrance of food into the mouth from the front absolutely impossible. There is, however, a small section of the mouth opening to the left side just behind the origins of the lower teeth which looks as though it could have been used. The hair around this corner of the mouth looks rubbed and worn thin. Possibly by turning the head to one side and by manipulating with the tongue as effectively as it could act under the permanent tongue depressor (the left upper incisor) some leaves and other small fractions of plant tissue could be forced far enough into the mouth to be caught and ground up by the back teeth.

Whatever explanation one makes concerning the method of feeding, the animal certainly obtained enough food to keep alive, for it was killed by the trapper. And from the date of capture, nearly a month after the normal woodchucks had disappeared, we can be just as sure that the creature had been unable to hibernate because incapable of accumulating fat.

There is no means of learning the age of the animal, but since these rodent teeth grow rapidly it was probably a young one and these tusk-like teeth the unworn accumulation of one season's growth. It seems impossible to imagine a half blind, deformed and infected animal ever having been able to store fat enough to live over even one hibernation period.

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SOME COMMON MISCONCEPTIONS OF EVOLUTION*

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The living world embraces such a variety of form and such a range of structure and mode of life that, to the average man without scientific training, it must always have seemed a great unravelable tangle, inexplicable on any other ground than that of special creation—that some omniscient and omnipotent being made the various forms of life and established them in the world, for his own delectation, if for no other purpose.

But the greater scientific and philosophic minds of the past centuries have been able to discern an order in the midst of this apparent chaos and, from the time of the ancient Greeks, repeated attempts have been made to point out this order and to suggest some more acceptable reason for its existence than to assume that somebody made it all at once and set it up ready to run to the end of time. Naturally, the earlier attempts to convince mankind that there has been a gradual evolution of the present complex order of existence were unsuccessful for want of sufficient knowledge.

It is probable that Aristotle, Lucretius, St. Augustine, Harvey, Buffon, Lamarck, Erasmus Darwin and other great minds of the past apprehended clearly enough the scheme of gradual development of life on the earth, but they lacked sufficient knowledge of the facts to make a convincing argument on a matter apparently so revolutionary. Furthermore, from Augustine on down, they were confronted by a dogmatic theology which effectually blocked the progress of scientific thought for many centuries.

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* Retiring President's Address before the Ohio Academy of Science, April 14, 1922.

The scientific men of the past century and a half, especially, have established the following important facts with regard to life on the earth:

1. There has been a gradual development from simpler to more complex forms.
2. There have originated multitudes of new species as well as whole new phyla since the geological record began.
3. Other multitudes of species as well as whole orders have passed out of existence in geological time.
4. These changes have been the result of orderly procedure and not of cataclysmic action.
5. There has been continuity of life and uniformity of biological processes.
6. Untold ages of time have been involved since life first appeared on the earth.

The only satisfactory explanation of these facts is found in organic evolution. All those who have the best right to an opinion on this matter—the scientists who have investigated and carefully weighed all the data, are agreed that there is no other satisfactory method of putting the facts together in logical order. All of the facts and deductions are open to re-examination, but as they have been carefully scrutinized already by large numbers of investigators and from all angles, it is not likely that any different interpretation will be found possible.

Notwithstanding this concensus of opinion among those qualified to judge, there has always been a number of "conscientious objectors" among those untrained in science, on the ground that evolution opposed certain established theological dogmas. A theistic conception of evolution, however, satisfied the more liberal minded of these objectors and there has been a gradual diminution of opposition since the time of Darwin. Recently, however, a well-known, quixotic platform speaker has made a virulent attack on the law of evolution and the weight of his oratory has carried so many people with him, that opposition to evolution has spread like an epidemic through certain portions of this country. If he had chosen, instead, to attack the Copernican theory that the planets revolve around the sun, he would no doubt have convinced many unthinking people and those unfamiliar with the facts. This campaign against a law of nature would be amusing were it not for the fact that it shows such a deplorable state of ignorance among our supposedly enlightened people, with regard to the progress of science.

It is true that many otherwise highly educated persons do not have a very clear idea of the law of evolution and that many misconceptions are current among them. In the effort to clear up some of these mistaken notions let us consider a few of those which appear to be most commonly held.

It is commonly, but mistakenly, supposed that scientific men are divided in opinion as to the truth of evolution. This idea has arisen from the discussion of certain minor matters, or side issues, such as the mode of origin of species. It may be safely stated that the only questions concerning evolution that are debated by the biological scientists, are those that have to do with the *method* of evolution—the discussion of the means employed by nature in causing the changes that are admitted to have taken place, and the paths along which the advancement occurred. Though there is still much discussion as to just how it has come about, no scientist at the present time has any doubt of the fact of evolution. Furthermore, all will admit that three great interacting factors are to be found in *variation*, however it may be caused; in *selection*, by which inadaptive changes are eliminated and adaptive changes permitted to continue; and in *heredity*, by which any advance, involving the constitution of the organism, may be perpetuated through succeeding generations.

Variations of some sort are necessary, of course, however they may be caused, or there could never be any change and, without change, naturally, no evolution. Moreover, the variations must be of a particular class, for they must be inheritable, and, as far as we know, only those variations are capable of being inherited which involve a change in the germ plasm. The "discontinuous variations" of Bateson and the "mutations of DeVries are the most marked of these germinal variations, but just how small a variation may be and still be inheritable no one has yet discovered. Variation, then, supplies the crude material for evolution.

Natural selection, that much misunderstood and much abused term!—selection is merely another way of stating the fact that variations of all sorts occur and that some of these may benefit an organism, while some others may be harmful to it.

The beneficial variations are of value to the organism in solving its problem of existence and, very naturally, such variations tend to insure that the organism shall live to maturity and through its reproductive period. If a variation is inimical to its possessor, then selection naturally eliminates the organism that possesses such a variation and that is the end of that variation, since, if its possessor does not live, the variation cannot be perpetuated.

Heredity is merely passing on to the next generation any characters which may be a part of the germ plasm of the organism. A species can find no way of continuing a variation that is sufficiently harmful to cause the death of its possessor, or even to pass on for very long a variation that is only mildly disadvantageous. To indicate how important even a slight advantage may be, allow me to quote from Prof. R. C. Punnett; "If a population contains .001% of a new variety, and if that variety has even a 5% selection advantage over the original form, the latter will almost completely disappear in less than a hundred generations." So, heredity becomes an important factor for progress when coupled with variation and selection, in that it gathers up the useful variations and concentrates them in posterity. Or, as Prof. J. A. Thomson puts it, "The true inwardness of heredity is a holding fast of that which is good."

A misconception of heredity lies in the notion that it can accomplish anything more than merely to pass on to future generations what has already become a part of the germ plasm. Just as selection has no evolutionary importance aside from its reaction on variations of different degrees of value in adaptation, so heredity has no place in evolution except as it passes along such characters as have been already selected out as of importance in the life of the organism. Any new variation of the germ plasm, of value, is in this sense selected and, by heredity, becomes a part of the more advanced organism, while any new detrimental variation is swamped by the struggle for existence and is not permitted to be passed along by heredity, because its possessor is eliminated as unfit to meet the conditions of life. It is possible, of course, for a character to be merely useless without being harmful, but such features of an organism must play a very small part in evolution.

Darwin's theory of Natural Selection has been blamed by undiscerning critics as being responsible for the Great War. Unfortunately the term "natural selection," which means nothing more than that one variation may have an advantage over another one under the conditions of nature, has been drawn into bad company by those who have misused it, as, for example, in association with the Neitzschian philosophy of the superman. As a sample, we may quote the following statement from von Bernhardi, "Wherever we look in Nature, we find that war is a fundamental law of evolution. This great verity, which has been recognized in past ages, has been convincingly demonstrated in modern times by Charles Darwin."

Now, Darwin made no such interpretation, and various later biologists have taken exception to this application of his theory to human affairs and especially to war. Thus Thomson wrote, five years before the war, in 1909, in "Darwinism and Human Life": "I find no grounds for interpreting Darwin's 'metaphorical phrase,' the struggle for existence, in any sense that would make it a justification for war between nations." Dr. Chalmers Mitchell also comes to the conclusion (Evolution and the War, 1915) that "They" (modern nations) "differ from the units of zoology and botany in that the individuals composing them are not united by blood-relationship. Even if the struggle for existence were the sole law that had shaped and trimmed the tree of life, it does not necessarily apply to the political communities of men, for these cohere not because of common descent, but because of bonds that are common to the human race."

A former president of this Academy, Prof. Maynard M. Metcalf, stated in his presidential address before the American Society of Zoologists on "Darwinism and Nations," "Human communities, especially, have freed their members from much of the stress of the struggle for existence, by substituting co-operation for rivalry. . . Co-operation may perhaps fairly be said to transcend natural selection as an influence upon the life of highly civilized man. The higher the development of human society, the more dominant becomes the principle of co-operation. Only in the most primitive communities can there be an approach to unrestricted natural selection. Indeed, we know today no such human societies, and it is probable that this stage of social evolution was already passed before man's ancestors became truly men" (Anatomical Record, Jan., 1918). Thomson again says, "The appeal to human history, which the militarists make confidently, has seemed to many to show that civilization was born out of war. But scientific inquiry does not confirm this conclusion." Havelock Ellis writes (1919) "War probably began late in the history of mankind," and, "War was a result, and not a cause, of social organization." As Thomson points out, "The militarists' appeal to history is not any more convincing than their appeal to biology. The facts are against them in both fields." Finally we should point out, as has been done by various biological writers, that war really is a detriment to both sides, especially between advanced nations, by destroying the best of the younger men, whom the nations at war can by no means afford to lose. Thus war, instead of being contributory to the selecting of the best and the survival of the fittest, too often results in the survival of the unfit on both sides, to the great detriment of the human race.

Thus no one has any cause to shudder at the mere term "natural selection," since, to its gross misapplication as an excuse for war, such as that made use of by ardent militarists, the biologists have as much fault to find as any one. None but the pre-war German philosophers would ever have agreed with von Moltke that "war is a part of God's world order," and the biologist, as much as any one, has a right to feel scandalized by the crass misinterpretation of the selection theory which has been placed upon it.

In a state of nature it is undoubtedly true that "the weaker go to the wall," if by the weaker we mean those that are the least adapted to meet the complex problem of existence, but that does not imply, even in lower animals, that there is usually anything like war between individuals of the same kind. The struggle is confined to the effort of each to maintain itself as an individual, and where competition is keen some have a natural advantage of organization over others and these can better solve the problem of existence while the others fall by the wayside. Of course, the term selection is unfortunate in that in the minds of many persons it is involved with the idea of conscious choice, but no biologist has any difficulty in holding to a proper interpretation of the term.

The notion seems to be prevalent that the proof of evolution hangs on the proof of the method of the origin of species. Now, it happens that the exact cause of the origin of species is still in doubt. This, however, is a comparatively small matter and the law of evolution does not depend upon its solution at all. We have abundant proof that multitudes of species have originated and some of these have been traced through the process of change, even if we do not know what caused the change. Would anyone deny the fact that chickens hatch out of hen's eggs, because the biologist does not pretend to know all the processes involved in the development of the embryo?

It would be extremely interesting to know the causes of the origin of species, but it is not necessary to the fact of evolution. The origin of species in the past is an incontrovertable fact, even if we do not know how they originate. Similarly, organic evolution is an incontrovertable fact, though we may not know all the processes concerned.

In recent years it has often been stated that "Darwinism is discredited" and the average person takes this statement to mean that *evolution is discredited*, for most people cannot seem to get through their heads the fact that *Darwinism* and *evolution are not synonymous*. To what extent Darwinism is discredited, however, depends entirely upon what we mean by the term "Darwinism." Darwin's great contribution was establishing the fact of evolution, than which no greater contribution has ever been made to the fields of science and philosophy.

There is no thought in the minds of scientists of any possibility of controverting evolution, any more than they would deny the Newtonian law of gravitation or the Copernican cosmology. If, however, we merely mean by Darwinism, the same reliance on natural selection of fortuitous variations as the method of origination of new species, which Darwin placed upon it, then we may admit that there are many honest doubters as to the *method* of evolution as stated by Darwin.

However, it is clear that the non-scientific public does not distinguish between the fact of organic evolution and Darwin's explanation of its cause. So, indiscriminating propagandists, opposed to evolution, fix upon the *discussion of Darwin's proposed method* and overlook entirely *the fact which all scientists are agreed upon*.

There are some controversialists again, who misuse, in opposing evolution, the discoveries of Bateson, DeVries, and others, in regard to mutations or larger steps, which throw some doubt on the validity of Darwin's belief in the great importance of minute variations. To accept the mutations of DeVries only means to hasten the process of evolution, since the steps in advance are so much greater than those suggested by Darwin. For, after all, mutations are only germinal, and therefore, hereditary, variations of a more noticeable character, and the acceptance of DeVries' views does not invalidate in the least the importance of the principles of variation, selection and heredity, but only makes possible the progress of evolution at a much more rapid rate than does the Darwinian method. Yet forsooth, because definite mutations are substituted for the minor and fortuitous variations of Darwin, the undiscriminating, ignorant and bigoted proclaim that evolution is overthrown. It would be as truthful to maintain that the Copernican theory of the movement of the planets around the sun is overthrown because a new asteroid is located now and then! Besides it has no bearing on the fact that evolution has taken place.

As to the controversy between those who hold with Darwin and those who agree with DeVries I can see no special difficulty. It may be that they are merely looking at different ends of the same series. Bateson and DeVries at first assumed that mutations must, of necessity, be breaks in the series, of considerable importance. Later investigations, however, have shown that mutations, or hereditary variations, may be much smaller than they were at first supposed to be necessary and, in fact, some of them are much less noticeable than some somatic variations acquired during the life of the individual and not heritable. The difference, which Darwin could not have known, is a qualitative one rather than quantitative, on the basis that to have any evolutionary value, a variation must affect the germ plasm and not merely the body of the individual. On the other hand too great a departure from the normal may have no evolutionary importance because it renders the individual unsuited for life or reproduction and so it is eliminated by natural selection.

It is a common misconception that evolution is a force or power by which things are brought to pass. Even the less discriminating biologists may not be entirely free from this notion, for I recall a little verse which used to be sung at Woods Hole, that Mecca of the biologist, which runs as follows:

> "Once I was a Rhizopod, a protoplasmic cell,
> I had a little nucleus and oh! I loved it well,
> Now I am a man at last, *by evolution's power,*
> But oh, my little nucleus! I need thee every hour."

Evolution is merely an explanation of the way things have come to be as they are, together with a statement of the natural laws under which this has taken place. It involves uniformity and continuity in nature and it applies to everything which has undergone change in the course of time.

Some of the confusion in the minds of those untrained in the methods of science is undoubtedly due to the lack of a clear understanding of what is meant by "natural law." A natural law is merely a formula indicating a method of procedure in nature. It is a statement based on the classification of facts and the comparison of their relationships. Civil law, as a man-made rule of conduct implies a restriction and compels conformity, and changes continuously with the varying conditions of human society. Natural laws are merely conclusions drawn from the scientific study of organized series of facts and are immutable except as they are modified by a re-classification and re-statement. A careful reading of the third chapter of Karl Pearson's "Grammar of Science" is recommended to all interested in this matter. "The civil law involves a command and a duty; the scientific law is a description, not a prescription. The civil law is valid only for a *special* community at a *special* time; the scientific law is valid for *all* normal human beings, and is unchangeable so long as their perceptive faculties remain at the same stage of development."

Another misconception of evolution is involved in the idea that it always means an advance of some sort toward higher organization. This idea is contrary to the very method of evolutionary processes. Variations may occur in any direction in any group of organisms, as far as we know, and, theoretically, at least, they are just as likely to be retrogressive as progressive. Secondary simplification is very commonly observed, especially in parasitic organisms.

But what we are especially concerned with in this discussion is progressive evolution in the sense that advances are made in the direction of complexity and the origin of what we are disposed to call higher animals, though we may be guilty of an anthropocentrism in so doing. From the standpoint of the Protozoan we might be considered degenerate, from the fact that our cells have lost their capacity for independent life, and have to live together or not at all. However, it is just this very loss of independence of the individual cell, involving the principle of division of labor and necessitating specialization for the better performance of some process and the co-operation of various parts, that has marked the advance of more complex organisms, whether we may be allowed to call them higher or not.

But variations may occur in all directions and it has often happened that the road to adaptation has lain in the direction of secondary simplification of structure, and selection, in such cases, means the elimination of the more complex, in order to adjust the animal more closely to its environment.

The crayfishes of our American caverns have lost their eyes, but they are highly adapted to a life in total darkness; the sessile ascidians lose nearly all semblance to vertebrate animals, which they clearly possess in the larval stage, by their adaptation to sessile life; the whales and seacows have lost the hind limbs and have taken on a fish-like form in adaptation to aquatic existence. Among parasitic forms we see this carried to the extreme. The tape-worm lacks entirely the intestinal tract, and the parasitic barnacle *Rhizocephala* is so profoundly degenerated that were it not for our knowledge of its development we would not be able to state even its affinities to the Crustacea. These degenerative changes, bringing about the loss of simplification of structures, are just as much the product of evolution as are the modification of a fore limb to a wing in the bird, the highly organized mammalian brain, or the complex social life of bees and ants. As Thomson remarks, "It is plain that evolution may be down as well as up, and that the gates of parasitism and other facile slopes of degenerate life are always open. The tapeworm in its inglorious ease is as much an outcome of evolution as the lark at heaven's gate."

On the other hand, a point on which the man who merely reads about evolution may be at fault, is in thinking that variations are always necessarily fortuitous and occur in a helter-skelter fashion. No doubt many variations are of this nature, but there appear to be others which are directive in their nature from the beginning and which keep on increasing in value with successive generations, the "rectigradations" of H. F. Osborn. The observation of this sort of serial successive variations has led to the suggestion of the principle of *orthogenesis* in evolution, the idea of successive changes along the same line, each going a little farther than its predecessor, so that in a comparatively short time a much greater distance has been compassed than would be possible by mere chance variation in any or all directions. The literature of paleontology is full of such examples, dealing with horns, teeth, limbs, spines, shells and other structures capable of fossilization. The only satisfactory explanation suggested to account for this, seems to be that a small chemical change in the germ plasm may make possible another change of like character and this supply the basis for the next step, and so on. Only on some such basis as this can we explain the evolution of certain structures which make their first appearance in such a small degree that they have no apparent value in selection and yet they keep on varying and advancing along the same line until the structure becomes either adaptive and of value to the organism or inadaptive to a degree sufficient to destroy the species. Such structures may sometimes rise from insignificant, non-selective stages to a condition of much importance, to the organism, but, having started to vary in one line the advance may keep on beyond the adaptive condition and finally become a menace to the species. Such conditions of racial senescence are known in numerous examples from the fossil records.

A mistake commonly made by those not engaged in biological work is to think that a great majority of the variations produced must have some value to the organism, since harmful variations are seldom noticed in nature. It is true that beneficial or at least harmless variations are the ones usually noticed, because harmful variations are not perpetuated very long. The biologist with an eye open to these things very often observes them, but they never last long and the more harmful ones never reach the next generation because they are fatal to the organisms in which they appear. In every species an abundance of such inimical variations may be observed to produce the death of the organism, even before hatching or birth.

The objection has often been raised by the less thoughtful critics of the evolution theory that the principles of selection and adaptation cannot be of much importance after all, since we see many cases where adaptations fail to work and where selection fails to eliminate such variations. A little more insight into the problem would indicate that, after all, any adaptation only needs to work sufficiently to be of benefit to the species *as a whole*, and not necessarily to all individuals. An adaptation is merely an adjustment to a certain condition of life, and if the condition is changed, naturally the adaptation does not exist; that is to say, the particular reason for the existence of a particular structure, process or instinct, does not obtain and therefore the organism is not adapted any longer. Undoubtedly the reason why it is so difficult to keep many wild animals in confinement, or why they often will not reproduce in captivity, is because we cannot supply the conditions for which they are adapted. A single adaptation is not a master key, it will unlock only one particular gate barring the pathway to existence, and if that gate is replaced by another, that key is useless, but it may not be dangerous to carry it.

There are, to be sure, many examples of imperfect adaptation to be found on every hand and the biologist has not failed to take them into account. The case should perhaps be stated something like this: Successful organisms, by which we mean all organisms that continue to exist, are fitted to meet in a satisfactory manner, the ordinary conditions of their natural environment. But the environment is always more or less variable and the adjustment can therefore seldom be perfect. The organism which is *able to pass the adjustment test with a sufficiently high rating* will get along.

Another misconception along this same line arises from the difficulty which man encounters in attempting to look at the results of evolution from an impartial standpoint. He cannot ordinarily escape from the limits of an anthropocentric evaluation of other organisms, and measures all other creatures by his own foot-rule. Yet aside from his high nervous organization it would seem that man has little to be proud of. Certainly, in many other systems, he is not to be compared in the perfection of his adaptations with multitudes of other animals. Bertrand Russell has facetiously remarked, "Organic life, we are told, has developed gradually from the protozoon to the philosopher, and this development, we are assured is indubitably an advance. Unfortunately it is the philosopher, not the protozoon, who gives us this assurance, and we can have no security that the impartial outsider would agree with the philosopher's self-complacent assumption."

Some one has referred to the results of selection as "the survival of the adapted," and adaptation means merely the ability to meet the conditions of existence in one way or another. All organisms that continue to exist, must therefore be adapted, and the supposedly lower organization of the protozoan may be just as effective as the more complex structure of the mammal. If the only proof of fitness is continued existence, then the Foraminifera, which have had a long and continuous career from the Cambrian period, at least, are far better organisms than were the Dinosaurs, which lasted only through a few millions of years in the Mesozoic and found continued existence impossible. Man, who has been on the earth only a mere half million years or so, has scarcely been given a fair trial to prove his fitness, and the probabilities are that the Foraminifera will continue to flourish long after man has definitely proved his inability to cope with changing conditions. We should, therefore, in justice to our logic, define carefully what we mean by "higher," for higher specialization does not imply higher adaptability.

A mistaken notion of evolution which has caused great concern to the uninitiated is that it is a theory about the origin of man from a monkey. Just why this idea should be so repellent to a large class of people is difficult to see, for after all monkeys are very respectable in comparison with some humans and, furthermore, they are very high in the scale of animal organization. We will all agree that they are incomparably higher than the "dust of the earth," which many persons seem to prefer for their ancestral stock.

But, of course, in thus speaking of the origin of man, no evolutionist has the modern anthropoid ape in mind any more than he has the modern man. Both are the evolutionary products of a common stock and have taken different directions, different lines of development. Their relationship lies through a common type of remote ancestor. To approach that relationship, one must go back to more primitive Primates, just as to find connecting links between the Primates and Carnivora one must go still farther back to more primitive mammals.

The nature of the "missing link" has exercised the mind of the non-biological world very greatly, because of an erroneous idea of what constitutes a missing link. As far as I am aware this is always popularly applied to the evolution of man and the usual opinion is that there should be found some intermediate form between man and the nearest anthropoid ape, or, because the general public is not informed or discerning in these matters, between man and a monkey. But no biologist would ever expect to find such a connecting link, for none could exist. Man and the apes are contemporaries and so it is impossible that one should descend or ascend from the other. As well might one expect to find the missing link between contemporary horses and tapirs, though both are descended from the same group of primitive ungulate mammals. What we do expect to find and what, in fact, we do find as we go back in time is that we unearth simpler and more primitive types of man until we come to a brain only two-thirds of its present size, a prognathous jaw, less erect posture, etc., and if we carry this far enough we will come to the generalized Primate stock. If we trace out the ancestry of the apes we will run back in a converging series to the same place. The only sort of a connection existing between man and the apes is that of origin from a similar source.

There is also a mistaken notion that evolution fails to account for the origin of the mind of man. But the modern psychologist and the student of animal behavior are agreed that there is no necessity for assuming any break in the continuity of the series of phenomena in the evolution of mind. The origin of mind is indissolubly linked up with the nature of protoplasm, in its automatic movements, tropisms and reactions. If we begin back as far as the protozoa, we may quote the statement of Jennings that even the Amoeba "behaves as if it had a mind of its own." From the indefinite condition of automatism, irritability and conductivity, exhibited by the lowest animals, we arrive by gradual steps through the better and better organization of a nervous system to a definite brain and the improvement of this organ through various stages in the vertebrates up to man, without a break. Parallel with this we see the development of reflex action, experimental behavior, instinct and learning, to intelligent behavior, inference and rational purpose.

The evolution theory has been before the world in a concrete form for more than sixty years and all scientific men, or those capable of forming a worth-while opinion, have been agreed on it almost without exception ever since the convincing statement of the case by Charles Darwin. Scientific men have generally shown themselves to be capable of forming sane opinions in their own field, but the general public still finds it a difficult matter to accept the word of the scientist, especially when scientific fact seems opposed to some long-standing belief, or common uncritically-judged experience. After nearly 400 years following the announcement of the Copernican theory, a fair share of people still believe the world to be flat, because all they can see of it looks that way. Many more still believe in witch-craft or the influence of evil spirits, and a still larger percentage hold firmly to the moon as a causative agent in the growth of crops, the curing of meat, etc., etc.

After having written the above paragraph the writer came across the following in the "Century Magazine" for February (1922) in an article on "The American Gypsy," by K. Bercovici: "The study of folk-lore * * * has demonstrated that a certain stratum of the population is never reached by the civilization of any given period. There are as many people today who believe in witch-craft and black magic as there were 500 years ago; as many people who go to fortune tellers to have them read the cards, the palms, or tell the future as seen in the bottom of an emptied coffee cup."

In the field of medicine, notwithstanding the advance of science, the general public is as gullible as ever, in the matter of cure-alls, elixirs and nostrums, advertised to heal all "the ills that flesh is heir to." A recent widely distributed advertisement of Dr. Morse's Indian Root Pills states for the benefit of the public that "Malaria is due to a poisonous miasma, which arising from the low swampy lands, becomes assimilated with the atmosphere," etc., while every scientific man has known for the past 25 years that it can be distributed only through the bite of an *Anopheles* mosquito.

There is scarcely a newspaper that does not occasionally carry an advertisement of an astrologer, a crystal gazer, a clairvoyant, or other similar kind of fakir, while the number of people who still consult the medical almanac for the signs of the zodiac and the changes of the moon is very large, even in the most enlightened countries. The traditional superstitions of the primitive civilization of our forefathers still hold sway in the minds of multitudes in spite of the advancement of the few.

This is easily understood in the uneducated and in that portion of the public whose intelligence rating is much below the average, for such people either have no capacity for much understanding, or no knowledge on which to base anything but an unscientific belief—and when you come to that kind of belief it is as easy to believe one thing as another, especially if you are not particular as to the basis for it. There is a line in an old hymn which runs to the effect that "blind unbelief is sure to err." It would have been equally true had it stated that blind belief is sure to err. It is the blindness in either case that results in the error. "Belief, in the scientific sense of the word," says Huxley, "is a serious matter, and needs strong foundations."

When we come to the educated portion of the public we have some right to expect more discrimination and less general credulity. We have a right to expect that they will refrain from attempts to discredit the work of capable scientists on the basis that it controverts some already established belief. An educated man should at least be able to draw the line between what he knows and what he doesn't know and not attempt to pass judgment on matters outside of his field of training. The educated man without scientific training has no more basis for forming a proper judgment of the Law of Evolution than of the Einstein Theory of Relativity.

I have said that *no scientist doubts the broad fact of evolution* in the organic and inorganic worlds, but it is equally true that in the minds of many of the unscientific, there still remains not only a doubt, but a positive conviction that evolution is merely a vague guess of the scientist and that it is not necessary to place any reliance on his views. If the question as to the truth of evolution were to be put to a public vote today, I have little doubt that the scientists would be overwhelmingly voted down.

The newspapers still mistake scientific discussions as to the *method* of evolution for doubts as to the *fact* of evolution and often herald this error in glaring headlines, such as "Great Scientist Disputes Darwinian Theory," "Evolution Theory Disproved," etc., etc. This happened no later than last winter following Prof. Bateson's address before the American Association for the Advancement of Science at Toronto. At the close of his address, Bateson said, "Let us then proclaim in precise and unmistakable language that our faith in evolution is unshaken. * * * Our doubts are not as to the reality or truth of evolution, but as to the origin of species, a technical, almost domestic problem. Any day that mystery may be solved." Though the greatest pains were taken to insure that no mistakes should creep into the subject matter presented to the newspapers for publication, the headliner got in his deadly work uncensored, with the result that the next morning's papers carried headlines announcing the unwarranted assertion that this famous British scientist disputed the fact of evolution.

It is quite apparent that the mass of the reading public are unable to distinguish the difference between fact and method in this field of thought. The campaign against evolution just now being waged by a certain notorious speaker is a case in point. When a man who is very evidently unskilled in the handling of scientific data, unfamiliar with the details of the subject, and solely by an appeal to the emotions through his oratorical presentation, can obtain a wide hearing throughout the country and can even influence a state legislature to consider measures for preventing the teaching of evolution, we must admit that the idea has not yet been fully accepted by many so-called educated people.

The editor of "The Congregationalist," (March 16, 1922, p. 326), however, wisely points out that "Addresses such as that which Mr. Bryan delivered in Philadelphia will do very little to affect the course of science, but we think they are calculated to do irreparable harm to religion." And again, "When one realizes the patience, care and courage with which the sincere scientist pursues his quest of truth, there is something anomalous in the effort to dominate that field by the superficialities of platform oratory."

Professors Henry Fairfield Osborn and Edwin Grant Conklin have also recently replied, through the "New York Times" of March 5, to an article by Mr. Bryan in an earlier number of the same paper. Osborn points out that "evolution takes its place with the gravitation law of Newton." Conklin comments on Bryan's attempt "to establish an inquisition for the trial of science at the bar of theology," and grows facetious over his proposition "to repeal a law of nature by a law of Kentucky."

Mr. Edward M. Kindle, of the Canadian Geological Survey, writes in a recent number of "Science," "A Don Quixote of Mr. Bryan's calibre only appears once or twice in a century and the opportunity to study in cold print the celebrated Nebraskan's proposal to resurrect the 'special creation of species' myth must be appreciated by our scientific brethren who are interested in studying the mysterious ways in which the human mind works when it approaches subjects unfamiliar to it."

It might be added that the English churchmen knew enough to quit fifty years ago when the proof of evolution was demonstrated to them. The modern opponents of the theory have not a single idea at their disposal that was not worn threadbare and proved useless a half century ago, while the facts supporting the theory have accumulated continuously and voluminously. The more enlightened churchmen the world over, long ago accepted evolution as one of the great fundamental truths, leaving only the ignorant and prejudiced among them to butt their heads against the wall of scientific evidence.

Why then, with this mass of evidence which is so clear to the mind trained in the formation of scientific conclusions, has not the general public been more ready to accept these conclusions? Has the public no faith in the findings of the trained scientist? It would seem so, not only in this matter, but in many others. Who is to blame for this condition of affairs? I fear that the scientists themselves are considerably at fault for not making more effort to place their discoveries before the public in such form that they can be "understanded of the people." Scientists have proved to be very poor propagandists. The facts and discoveries of science are so interesting to them that they go from one research to another without attempting to make clear to others what they have accomplished. If investigators are constitutionally unable to make their meaning clear to the reading public, then we need a group of interpreters who will make it their purpose in life to investigate the investigators and make known the truths of science to the masses of people who may be able to understand, if the facts are written in their language.

Just where does the evolution theory stand today in the minds of scientific men engaged on problems connected with this field of knowledge.

1. That there has been a cosmic evolution, no one familiar with the facts can doubt, though we may still be unsatisfied as to the truth of the nebular hypothesis of Laplace or the aggregation theory of Chamberlain as they concern the formation of the earth.

2. That there has been evolution, in the form of progressive changes of the earth itself, no one capable of forming a proper judgment can doubt, though we may still question the number of aeons it has taken to round the surface of the earth into its present form, and the exact mode of formation of certain rocks and strata may still puzzle us somewhat.

3. That there has been an evolution of organic life on the earth no one familiar with the accumulated data will doubt for a moment. The facts are so patent that one does not even have to possess a very logical mind to be convinced of the truth. The succession of animals and plants from lower to higher forms in past time, as shown by paleontological studies, is as clear and straightforward as any story which research has ever brought to light. This, coupled with the facts of embryology and comparative anatomy, yields a truth which no unprejudiced man can deny. For any one to do so merely proclaims his narrow-mindedness and prejudice and classes him among those of the last degree of blindness who "will not see."

4. That modern man himself is just as patently a product of evolution is clear to anyone familiar with the findings of paleontological anthropology, even if we do not consider the evidence from embryology and comparative anatomy. Our knowledge of fossil man takes us back through several extinct

human species—Neanderthal, Heidelberg, Piltdown, Foxhall and Trinil Man. These extend successively farther and farther back, through the different glacial periods to the later Pliocene, over time variously reckoned in years around 500,000. Through this succession of human species we can trace the gradual development of the cranial capacity to an increase of at least 50%; the retraction of the face from a prognathous to an orthognathous condition, the development of a chin, making possible the free use of the tongue in speech; the completion of the erect posture, and various other features by which man has become physically differentiated from his nearest animal kin. Along with this physical progress we can trace, *pari passu*, the evolution of his civilization.

Granted that we do not yet know all the processes by which these changes in man have come about, the fact that they have come to pass is so evident that only the ignorant, or he who willfully ignores the truth for his own ends, will attempt to dispute the fact. Place what interpretation on it you wish, the fact remains. I hold no quarrel with the man who accepts the fact and interprets it as the method of a supreme being for working out his eternal plan, or, as John Fiske said, "God's way of doing things."

Only we must not let our religious *beliefs* get the better of our common sense appreciation of *facts* in this or any other matter. There is no thing as sacred as truth, in whatever form it comes, and if it interferes even with a long-established belief, then it is time that the basis for that belief is looked into.

We have seen that the evidence of evolution does not rest on guesses or interpretation, but on facts, and not in one field only, but that astronomy, physics, chemistry, geology and all the biological sciences tell the same story in the same way, that of uniformity, continuity and progressive changes.

Gradually, of course, this natural law will receive general acceptance among the reading and thinking public. In the meantime, whenever some misinformed or bigoted egotist displays his ignorance of scientific matters, there are two things which we may do; either we may attack his mis-statements and set the unscientific public in the right through the press, or we may follow the plan adopted by the man who was kicked by a mule, and just "consider the source."

DYNAMICS OF THE LITHOSPHERE.*

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INTRODUCTION.

It is a characteristic of the human mind that the things least easily understood are the things most desirable to know; and this insatiate curiosity frequently devises means to unlock the hidden and to overcome the impossible. It has been in large measure this psychological impetus that has prompted studies dealing with the unattainable central structure of our globe, and with the slow, invisible adjustments and responses, to which terrestrial matter is subject.

By lithosphere is meant the solid or rock part of the earth, not water and air, but probably all the rest from center to circumference. In order to gain an accurate impression of the adjustments taking place in the earth's outer part and of its physical condition, it is necessary to consider the whole problem of the interior of the earth. All evidence relating to the physical condition of the interior of the earth or to the adjustments of the earth's substance will, therefore, be first drawn together without statement of its reference to the problem; then conclusions will be drawn from the facts. In this way the influence of theories which may or may not be true will be avoided to some extent.

Our thesis is that essentially all the problems of the dynamics of the lithosphere resolve themselves into the problem of adjustment of strains and stresses in the structures and materials of the earth, adjustment to the equilibrium form of the earth, through the force of gravity, involving diastrophism, vulcanism, and gradation.

THE ASTRONOMICAL AND PHYSICAL DATA.

Astronomy has furnished the geologist three lines of argument pertaining to the physical condition of the earth's substance: These are precession and nutation, variation of latitude, the shape of the earth.

Precession.—Because the axis of the earth describes a cone in its motions, tracing a circle about the pole of the ecliptic, the equator, which preserves about the same inclination to the ecliptic, moves so that its intersections with the ecliptic pass in a retrograde direction opposite to the earth. This motion is termed the precession of the equinoxes.[1] Precession

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[1] Encyclopoedia Britannica.

is caused by the fact that the attractions of the sun and moon are not a single force acting through the earth's center of gravity. Since the variation is due to the attraction of forces which are estimatable, methods of calculation are possible by which the mass of the earth may be revealed.

Nutation[2] is a vibratory motion of the earth's axis, producing a wavy circle of precession, due to the unequal attraction of the moon on the equatorial ring of the earth. This, too, affords another method or means of calculating the earth's mass.

Variation of latitude[3−5] is caused by a shifting of the axis of rotation within the sphere so that its polar extremities wander in a circle of about fifteen (15) meters in diameter. By computation it should have a period of 305 days; but Chandler, from a great mass of data, discovered an actual period of 427 days.[4] Such a retardation can be due only to a shifting of the equatorial bulge, by the lagging adjustment of which retardation of the period is effected. Now since adjustment in the rocks is slow and incomplete, a tide must be set up in response to the strains developed by the shifting of the axis, because water is very adaptable to external force. Dr. Bakheyzer and Mr. Christie have independently investigated this problem of tides and both conclude that there is a tidal variation with about a 430-day period.

The shape of the earth [6−7] has been a subject of long and extensive study into which we do not need to enter. Suffice it to say that the shape has been determined to be very nearly an ellipsoid of revolution, showing that the earth's substance is sufficiently plastic to be nearly perfectly adjustable to rotational forces. The superficial exceptions will be discussed later.

Schweyder[8] has recently determined the nutation period as 432.8 days.

The physical data throwing light on the condition and responsiveness of the earth's substance are varied and extensive.

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[2] Encyclopoedia Britannica.

[3] Ibid.

[4] Darwin: Tides, Chap. xv.

[5] Chamberlain, Reed, Hayford Schlesinger, Smithsonian Rpt., 1916.

[6] Encyclopoedia Britannica.

[7] Poynting & Thompson: Text Book on Physics.

[8] Schweyder W. Naturwissenschaften, 1917, Potsdam, Germany, pt. 38. Quoted from Jour. Geol. 1921, v. 29, p. 396.

The plumb line[9–10] has been used near mountains to estimate the mass of the earth. The deflection from the vertical, due to the attraction of the mountain, is measured. The mass of the mountain is then calculated, and from these data the mass of the earth is calculated. By this method Maskelyne, in 1775, secured a mean density of 5. and James, in 1854, obtained 5.32.

The pendulum[9–10] was first used by Bouguer. The number of swings of the pendulum at the surface are compared with the number on a mountain, and the comparative attraction worked out. Carlini, 1821, obtained a mean density of the earth of 4.84; Airy, 1854, obtained 6.57; Pechman, 1865, 6.13; Mendenhall, 1880, 5.77; Sterneck, 1883, 4.77, and in 1885, 6.77; Preston, 1892, 5.13.

The Cavendish method.—In this experiment two small balls are placed at opposite ends of a wire and their movement measured when attracted by a large ball of known mass. A comparison is then made between the attraction of the earth and the attraction of the ball. Cavendish, in 1798, found 5.45 to be the mean density of the earth; Bailey, 1843, secured 5.67; Reide, 1852, 5.58; Corme and Baille, 1878, 5.5; Wilsing, 1889, 5.56; Preston, Bays and Braun, in 1895 and 1896, all secured 5.53; in 1902, Burgess obtained 5.55.

The chemical balance has been successfully used by determining the attraction of a known mass placed above or below the scale, and comparing with mass of earth. By this method Poynting, 1891, secured a specific gravity of the earth of 5.49; and Richarz and Krigar Menzel in 1898 obtained 5.51.

Tides.—The evidence from tides is very simple yet very conclusive. If the earth is liquid with a crust or lacking in rigidity, then the entire crust will yield for a tide; but if it is rigid—as rigid as steel—there will be some rock tide, but the tidal force will be largely consumed in raising tides in the more responsive hydrosphere. Calculations on the height of tides by Darwin[11] and others shows that the tides are exactly what are to be expected on an earth of the rigidity of steel. Prof. Millikan has, however, measured tides in the rocks.

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[9] New International Encyclopoedia.

[10] Osmond Fisher: Physics of Earth's Crust.

[11] Darwin: Tides.

Support of load.—Physicists have pointed out that a liquid interior would not support continental masses rising 3,600 to 5,400[12] meters above the ocean floor.' But probably this argument is of little value when isostatic measurements have shown them to be of lower specific gravity.

Relative density of solidified and molton rocks[13] is such that a crust could not permanently form on a molten sphere in which convection currents are possible, since solidified rocks are denser than molten rocks.

Behavior of rocks under pressure.—It is a well-known law of physics that the melting point increases or rises with pressure[14]. Barus found the rise of the melting point of diabase to increase directly as the pressure. This would give a melting point of 76,000° C. at the center of the earth. Under such pressures as exist at the center of the earth, many physicists claim, it would be impossible to obtain molten rocks, because such an adjustment would be necessary as gave the least space, and it is certain that crystalline rocks occupy less space than molten rocks do. An increment of temperature increase amounting to about 1° C. for every 18 meters of descent has been found. Assuming the radius to be 6,268 km., this would give a temperature of 347,600° C. at the center, which is more than four times the melting point of diabase under the pressures assumed at the center. But it is unlikely that such a rate of increase can be supposed. Deeper borings seem to indicate a lessening rate, and a point may be attained, perhaps comparatively near the surface, where temperature ceases to rise. It is not our problem to account for the heat. It may be due to the mechanical work done, to radio-activity, to chemical action, or compression, or all together.

Another line of experiment giving some possible light on the condition of the interior of the earth is furnished by those investigations dealing with the crushing and flowage of rock. Van Hise[15] states that more than 1,700 kilograms of pressure per square centimeter are necessary to crush granite.

Fisher[16] has estimated 3,000,000 atmospheres of pressure at the earth's center.

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[12] Chamberlin & Salisbury, Text II, 7.

[13] Fisher: Physics of Earth's Crust.

[14] Chamberlin and Salisbury: Textbook in Geology II, 7.

[15] Van Hise: Principles of Pre-Cambrian Geol., U. S. G. S., 16th Annual Report.

[16] Fisher: Physics of Earth's Crust.

Hayford[17] and Bowie give the crushing strength of granite as about 1,425 kilograms per square centimeter, which place the zone of no cavities at âbout 8 kilometers. Van Hise, working on this problem, using the crushing point of rock as 1,700 kilograms per square centimeter, obtained adepth of 10,000–12,000 meters.

GEOLOGIC AND SEISMOGRAPHIC DATA.

Geologic Climates.—It was the problem of variability of geologic climate that caused the final overthrow of the Laplacian hypothesis. There have been in geologic history seven periods of climatic change.[18] Four of these have been glacial periods: the first two, early and late proterozoic, are well down the geologic column, and indicate a cold climate early in geologic history not at all reconcilable with a cooling globe, which is implied by a molten interior. The other periods of climatic change are the Silurian, Permian, Triassic, Cretaceous, Eocene, and Pleistocene, of which the Permian and Pleistocene are glacial.

"*Original Crust*".—The great granite embossments of Scandinavia, Canada, and other countries, formerly believed to be the exposed surface of the original crust, have been shown to be but intrusions in older sedimentary rocks, or in some cases greatly altered sediments.[19] The fact that there are now no known exposures of the original crust, certainly none that could have served as an original source of the sedimentary rocks—such a lack of original feeding grounds, certainly militated against the idea of an original crust at all.

It is obvious, too, that if our earth has been built up from planetesimals which have been gathered in upon a nucleus there will be no uniform gradation of material in any direction, nor any zoning into concentric layers so that any one layer will be essentially homogeneous as to density, melting point and composition. Presumably this heterogenity is not as great as it was ages ago when the infall of planetesimals was more frequent and when the larger part of the accretionary accumulation was not so far remote.

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[17] Hayford and Bowie: Spec. Rept., U. S. C. & G. S.

[18] Pirsson and Schuchert: Text Book of Geol.

[19] Chamberlin, T. C., 1916, Smithsonian Rpt.

This theory leaves no place for a "crust" conception as in the La Placian theory. But it does make place for enough variation in the composition and fusibility of earth materials even at the same depth that given a certain temperature in a zone only parts will become fluid. Fluid parts might tend to rise toward the surface. Parts remaining solid must then collapse leaving a solid zone. This would tend to produce a zonal arrangement of the earth materials. That such a gigantic banding is not perfected is shown by the persistence of volcanic intrusion and probably by diastrophism.

Geographic Distribution of Igneous Intrusion.—A third line of evidence is that afforded by the extent and distribution of igneous intrusion.[17] Were a molten globe surrounded by a thin crust, strains and stresses within the sphere would be in large measure relieved by igneous extrusion. The extent of igneous extrusion does not seem in any way commensurate with the stresses that are found. The localization of its geographic extension to certain well-defined areas would hardly be expected of lavas extruded from a molten interior; and it is therefore unlikely that igneous phenomena have more than a local and perhaps rather shallow source.

Seismographic Records.—The invention of the seismograph, by which earth tremors are automatically recorded with the exact time of their occurrence, has contributed much to the solution of our problem. From every seismic focus there proceed three sets of waves: those that travel along the surface and those that pass through the earth, of which there are two kinds—compressional and distortional.[20] Those which pass through the interior increase in velocity with depth below the surface, and increase more rapidly than the density, showing that the earth is rigid, and that its rigidity increases toward the center. Waves have never been recorded along a diameter, but as far as they have passed into the earth's interior, geologists may be sure that the earth is solid, for transverse waves cannot exist in a liquid and they are always recorded with the longitudinal (compressional) waves.

These records have made it possible to get at the depth of the seismic focus. In the case of the Neapolitan earthquake 10½ kilometers was the calculated depth.[21] The mean depth

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[20] Interior of Earth: Oldham, Q. J., G. S. Lon., v. 62, 1906.

[21] Davidson: Earthquakes.

of the focus in the Ischian disturbance was about 500 meters., and of the Andalusian of 1884, 12½ kilometers; the Charleston showed a depth of seven and one-third kilometers, and the Rivera 18 kilometers. The San Francisco earthquake showed a depth of disturbance of about 24 kilometers.

Many attempts have been made to measure the velocity of the waves at the surface, but with such varying results as to indicate inaccuracy of method or data, or perhaps to some degree to indicate varying density.

THE DATA OF ISOSTASY.[22]

Isostasy is the theory that any given column of rock taken from the center of the earth to the surface will have the same mass as any other column of the same cross-sectional dimensions. But as density of rocks varies the height of the column will vary. The inequality of density, however, is found only in the part of the column near the surface, and the difference in the length of the column is due to difference of density in the upper 122 kilometers (77 miles) of the column. The adjustment of material toward this balance under the force of gravity is called "isostatic adjustment." Defective density resulting in a taller column and excessive density causing oceanic basins, that is, a shorter column, constitute "isostatic compensation."

The density of any given column is calculated from the vertical component of the forces operative on a swinging pendulum or the forces deflecting a plumb-bob. ·Corrections must be made for the effect of topography. The pendulum method has been found most satisfactory and is generally used.

The scheme followed by the U. S. Coast and Geodetic Survey is as follows: eighty-nine stations were selected in the United States, and sixteen over the rest of the world. At these stations pendulum apparatus is set up, and the vertical component of gravity worked out. In order to correct for topography the entire earth is divided into 317 compartments, and the effect of each compartment computed. These corrections are applied to obtain the actual value of gravity due to density below the station. Next the value of gravity at the station is computed, a mean surface density of 2.67 being

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[22] Special Rpt. No. 10, U. S. C. & G. S., pp. 6, 7, 108.

assumed. The computed density subtracted from the observed density gives an anomaly which is approximately 1 part error and 4 parts departure in density from the normal. When observed density is less than the computed density the anomaly is negative. The anomalies thus secured bear no relation to topography.

The following conclusions have been pointed out:

1. The anomalies bear no definite relation to loading and unloading.
2. The United States is in isostatic adjustment with a mean departure of 171 m. of rock with 2.67 density.
3. A relation to geologic formation exists by which the older formations have a positive anomaly.
4. Intrusive and effusive rocks give an anomaly very near to complete and perfect isostatic compensation.

DATA OF DIASTROPHISM.[23]

It is hardly necessary to review here the evidence of actual crustal movement. One might, however, mention a few of the most important, such as mountain making, folding, faulting, tilting of lakes, elevated or depressed shorelines with their familiar accompanying physiographic features, actual measurement of movements, and submergence of oceanic islands. There was much change of level in and after the Pleistocene in the Great Lakes region, in Scotland, and in Scandinavia.[24]

The most noticeable fact of diastrophism is that it is most intense in regions of thick sedimentation, that is, where geosynclines have been filled. The Appalachian geosyncline presents 12,000 meters of sediment; others have nearly as great thickness; 10,000 meters are found in the Laramide structure; 3,000 meters of Eocene rocks were deposited in the Rocky Mountain geosyncline. The Alps present 15,000 meters of sediment.

Experiments reveal an expansive coefficient of 1 cm. to 19.2 meters for every rise of 100° C. in average rock. In the case of the Appalachians, 800° at the bottom of the geosyncline would have given 1650 meters expansion. In Pennsylvania

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[23] The most satisfactory discussion of the facts and theories of this problem is found in Dana's Manual of Geology, fourth edition.

[24] W. B. Wright: Quaternary Ice Age, 1914, pp. 406-426.

the actual shortening lies between 70 and 140 km., thoroughly beyond the power of increased temperature to create.

Intense normal faulting follows intense folding almost without exception.

Extensive faulting is usually apparently confined to regions of thick sedimentation. It is difficult, however, to detect faults in igneous rocks, also in some metamorphics. This may help to explain the apparent distribution of faults.

THE CENTROSPHERE.

The term "centrosphere" may be used to include that portion of the earth throughout which rocks are adjustable to stress through flowage, and in which cavities and fractures do not exist. It would thus be within the so-called "crust" or zone of fracture. The seismographic evidence shows two very important things in regard to this interior; first that it is solid, because it everywhere transmits transverse waves, which cannot pass through a liquid—this evidence is conclusive; secondly, that it is increasingly dense toward the center, attaining a specific gravity of 6 at .4 radius distance from the center—evidence calculated from the rate of wave transmission through the interior. At this rate of progression a density of 8.22 would be attained at the center, assuming the surface density to be 2.67. It is unlikely that this progression holds beyond this depth, because the mean density of 5.6 requires a central density of 11. Down to a depth of .6 radius the increased density is thought to be only that due to increased pressure; below this depth the earthquake researches of Oldham[27] may throw some light on the problem. He found that at a distance of approximately of 130 degrees from the point of origin, distortional waves were suddenly broken off to be continued beyond this distance approximately 11 minutes later. Just what inferences should be drawn from this, it is not possible to say, except that it is altogether likely that there exists a central core of about .4 radius extent from the center, required by other facts to have a density very high, probably between 8 and 11, and if dense to have a refraction of at least 2.

Some conclusions may be drawn as to rock flowage through the centrosphere. Granite has a crushing strength of 1,425 kgm. per cm.[25] while the pressure at the center of the earth is estimated at approximately 3,380,000 kgm. per sq. cm.[26] There can be no question but that rocks under these conditions will readily adjust to stress or strain. Yet Oldham[27] calculates that waves emerging at a point 90 degrees distant from their origin have passed through material having 12 times the resistance of granite and 15 times its rigidity. He adds: "Probably this is only what can be traced to increased pressure."

THE CRUST.

The term "crust" is used to describe that portion of the earth which lies above the level of compensation, and consequently includes all fractures, cavities, and most of the adjustment of the earth's solid substance. Crust and centrosphere constitute the lithosphere.

Depth.—Isostatic investigations have placed the compensation surface—by which is meant the surface at which compensation is complete—at 122 kilometers, which seems by results obtained to be near the truth; from other evidence the allowance seems ample. Van Hise, assuming the crushing strength of rocks to be 1,700 kilograms per square centimeter, surface density to be 2.7, and cavities to be supported by hydrostatic pressure, found that no cavities or crevasses would be possible at a depth of 10,000–12,000 meters. Fracture, however, might occur at this depth. Seismographic evidence would bear out this conclusion. Most seismic foci lie above 17 kilometers of depth. In the case of the Neapolitan earthquake, the deepest estimate fell near 39 kilometers, although the mean depth fell at 10½ kilometers. It is unlikely that this estimate is correct, because of the imperfect methods of calculation and the unknown density of the rocks through which the waves passed. Assuming it to be correct, it is still a very shallow phenomenon and well within the limits of 122 kilometers. Oldham[28] believes the more or less heterogeneous material may not be more than a score of miles thick.

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[25] Special Rpt. No. 10, U. S. C. & G. Survey, p. 111.

[26] Fisher, O.: Physics of the Earth's Crust.

[27] Oldham: Some Conclusions as to the Interior of the Earth. Q. J. Geol. Soc. Lond. (1906), V. 62, p. 456-75; Vol. 63, pp. 344-350.

[28] Oldham, R. D., loc. cit.

Density.—Surface density by estimation of its known components cannot be far from 2.67. A gradual increase with pressure due to recoalescence, and compression and inclusion of gases, due also to the closing of cavities, might be expected. This gradual increase is supported by seismic investigations.

This topic and many others have been elucidated by the recent papers of the Chamberlins in Jour. of Geol. Vol. 29–30.

Adjustability.—The most important result of our studies is the establishment of the fact that adjustment throughout the crust to external forces or to internal stresses is almost perfect. We have seen that the variation of latitude occurs because the equatorial bulge persists in shifting with the shift of axis. But back of this wehave evidence of adjustmentin the shape ofthe earth itself, which is very nearly the true form of an ellipsoid of revolution. That it varies at all from this form is evidence, equally good, perhaps better, of its plasticity. Its apparent inequalities are the result of its adjustment of heterogeneous density to the equilibrium of the ellipsoid of revolution. (See note.) We believe that the whole problem of volcanism, mountain-making, continent and ocean-basin formations, and all diastrophism are but phases of the problem of maintaining adjustment to this form of the earth. That this adjustment is nearly perfect, having an average departure of only 171 meters of rock of 2.67 specific gravity in the United States, has been proven beyond the stage of hypothesis. Even the maximum anomaly or lack of adjustment found in the United States corresponded to a stratum only 1,000 meters thick or a deficiency of pressure of 278 kilograms per square cm. or less than one-fifth the crushing strength of granite. This is an extreme and unusual anomaly. That this adjustment has been demonstrated in a broad way in regard to ocean basins and continental masses is beyond doubt.

The fact that there is essentially no relation to loading and unloading in the gravity anomalies would indicate rather rigid adjustment. The quick submergence of volcanic islands having a positive anomaly is also good evidence. There is no doubt that the area of deficient density through Nevada, part of Colorado, Arizona, and Southern California is in a stage of uplift.

NOTE—By equilibrium is meant an equilibrium of density, essentially what is implied in the term "isostasy."

Volcanism.[29]—The evidence of geographic distribution, extent of extrusion, and differentiation of magmas indicates that volcanism is a local phenomenon. Seismic evidence clinches the argument.[30] Distortional waves will not pass through a liquid, yet they pass with perfect freedom through any part of the crust at which observations have been made. There cannot, therefore, be any considerable lava lakes beneath the earth's surface. Isostatic investigations throw an illuminating line of evidence on the problem. Igneous intrusions and extrusions of all rocks are almost perfectly compensated.[31] It would seem then that volcanism is simply one method of quick adjustment to the equilibrium figure. It would be found in places of defective density where decreased pressure produces liquefaction in the form of a vesicle which rises to the surface, and in one way or another is ejected by force. Most of the vesicles stop before they reach the surface. Denser material is thereby added to, or replaces, lighter material bringing about isostatic compensation. The method would appear to be thoroughly delicate to reach isostatic adjustment so perfectly. One would expect the process once set off to continue this inertia beyond the point of perfect compensation. This is known to occur frequently in the case of volcanic islands that are thrown up with a positive anomaly, but which soon sink into a state of equilibrium.

Mountain Making.—This is another process resulting from the tendency of the crustal substance to maintain a state of equilibrium in reference to the figure of the earth through the force of gravity. The process is this: Marine sediments are laid down in a geosyncline, or along the edge of a continent. To maintain adjustment subsidence takes place until great depths of sediments are found. Isostatic adjustment is practically perfect throughout the process. The sediments thus laid down have, of course, a lesser density than the sediments or rocks on either side. There is, therefore, an imperfect horizontal adjustment to the bottom of the geosyncline. Now, as the sediments are forced downward temperature rises. Probably 800 degrees is attained at the bottom of the geosyncline, and since it contains rocks with more or less water inclusion, the steam developed, or at least the heated water when pressure is too great

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[29] Iddings: Problem of Volcanism.
[30] Smithsonian Rpt. (1916), The Earth's Figure, etc.
[31] Special Rpt. No. 10, U. S. C. & G. Survey.

for steam, weakens the rocks, and the expansion caused by increased temperature, amounting to 1 cm. to every 19.2 meters for every 100 degrees C. rise of temperature, causes a slight disturbance which is carried on by the pressure from the sides; erosion and deepening of the geosyncline tend to maintain isostatic adjustment throughout the process. Now inertia may carry the process beyond isostatic adjustment; certainly the rock thus thrown up cools to some extent. Both things may occur; at least there is always a period of normal faulting[32] succeeding a period of folding which might be caused by these factors. The mountain making process may be aided by lateral pressure developed by crustal expansion due to rising temperature of the crust. This, however, is mere supposition, and perhaps unsupported by geologic evidence.

Faulting is another process through which equilibrium is maintained. It differs from mountain making largely in that rock flowage and bending are predominant there; whereas faulting is the result of adjustment with fracture of the rocks rather than flow. It is not usually associated with the deeper synclines, although it is confined probably to regions of rather deep sedimentations.

Causes of lack of adjustment may be external, such as the tidal influence of the sun or moon, the shifting of the rotational axis, pressure of the atmosphere, increased load due to formation of glaciers, or the accompanying emptying of the seas, great evaporation or excessive precipitation; but probably the great cause of lack of adjustment is the shift of load due to erosion.

Earthquakes, so far as is known, present no opposition to our thesis that all the dynamics of the crust are the result of processes of adjustment of heterogeneous density to the form of the earth through the forces of gravity. The fact that calculations of depth of focus invariably indicate not a point but a plane lying more or less vertical to the surface, and that many earthquakes actually accompany slipping along a fault plane, would indicate that the phenomena of tectonic earthquakes are invariably of this character. The fact that many earthquakes show merely lateral stresses without elevation or depression in no way militates against our general thesis. Lateral stresses

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[32] T. M. Reade: Evolution of Earth Structure, p. 137-8.

would be set up in surrounding rocks by elevation or depression at a distance without local diastrophism. The amount of accumulated stress resulting in sudden adjustment by fracture and displacement will depend upon (1) the intensity of the lateral stresses, and (2) the plasticity of the rocks by which strain and stress can be adjusted without fracture.

Continental Creep has not entered into our studies. It is not, however, too much to suppose, since we know the rocks to be highly plastic, that the difference of pressure on the land side and water side of the continental slope will result in creep toward the ocean; the same sort of phenomena that give rise to mountains. Yet if this is true, the whole process maintains isostatic adjustment throughout, for anomalies of gravity nowhere indicate a general excess of gravity along the continental platform, which lack of adjustment would require.

Some Immediate Causes of Adjustments.—While much of the evidence presented in this section on "The Crust" indicates rather rapid adjustment to anomalies, it is true that there would be no anomalies if the adjustment did not lag more or less behind the causes which produce maladjustments. This is only another way of saying that stresses and strains are cumulative, that they may be held by the structures for some time, but that ultimately the earth structure has failed to hold them, as shown by Leith.[33] If the strains are held a longer time and become great, their release causes large and widespread adjustments. If the stresses are frequently released, only smaller and often local adjustments are necessary. When the balance of stress and structural strength is almost struck, but little is necessary to start adjustments. Tides, distant earthquakes, or even changes in atmospheric pressure are believed to be competent to start potential movements.

Deltas furnish a good line of evidence of almost continuous adjustment, for if adjustment did not take place rather rapidly, deltas and other areas of loading would indicate a positive anomaly. A positive anomaly is found at the mouth of the Hudson and through the Chesapeake Bay region. But we know that these areas are in a stage of subsidence, so that adjustment, if not complete, is taking place. On the other hand the delta of the Mississippi shows negative anomaly, due perhaps to the

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[33] C. K. Leith, Structural Failure of the Lithosphere, Science, 1921, pp. 195 ff.

tending of physical movements to carry beyond adjustment through inertia.

Continental masses and ocean basins have been demonstrated through isostatic measurements to be in isostatic compensation. This means that the continents and basins must be due to differential density, and that in this large configuration the shape of the crust is still in accordance with our thesis. Earthquake studies have thrown light on this problem also.[34]

CONCLUSION.

We have seen that the phenomena of mountain-making, volcanism, faulting, and earthquakes, together with density differentiations, are due to the processes of adjustment, through gravity of varying mass, to the equilibrium figure of the earth, and that continental creep and sedimentary loading, especially in deltas, though not due to this cause, yet are kept in isostatic adjustment. Our conclusion is therefore as follows: the dynamics of the lithosphere are essentially the processes of adjustment of strains and stresses in the varied structures and materials of the earth, adjustments to the equilibrium form of the earth, through the force of gravity, involving diastrophism, volcanism, and gradation.

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[34] Oldham, R. D., Q. J. G. S. London, Vol. 63, 1907, pp. 344-350.

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SOME BIONOMICS OF ALPHELINUS SEMIFLAVUS (HOWARD)*

Chalcid Parasite of Aphids

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CONTENTS.

GENERAL CONSIDERATIONS.

Aphelinus semiflavus How. is one of a few species from the genus *Aphelinus*, of the Chalcidoid family Eulophidæ, known to attack aphids. The others are scale parasites. At present there are but seven described species for North America, recorded as aphid feeders; namely, *Aphelinus mali* Hald., *A. nigritus* How., *A. Semiflavus* How., *A. Flaviceps* How., *A. Lapisligni* How., *A. varicornis* Gir., and *A. automatus* Gir. In addition to this number, the writer has recently taken two new species: one from an aphid on potato sprouts in the State Insectary at Whittier, California, and the other from *Sanbornia juniperi* Perg., an aphid on juniper in Pennsylvania. Both are being described by Dr. L. O. Howard.

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* Contribution from the Department of Zoology and Entomology, Ohio State University, No. 70.

These parasites, so far as known, are limited to the aphids as hosts, and most, if not all of them, are confined to a few species. *Aphelinus mali* was long considered an exception, appearing many times in the records as a scale parasite, also. However, Dr. Howard,* authority on the group, now believes these records to be in error, and further states that it is probably not only confined to aphids, but is likely restricted to the woolly forms, especially the common *Eriosoma lanigera* Hausm., of the apple, a species often associated with scale insects; a fact which may account for the confusion in the records.

The group, on the whole, are extremely minute and inconspicuous insects, not often met with by the average entomologist. Many of the species are quite rare, even to the specialist on the alert for them. At best they rank secondary to the Braconid subfamily Aphidinini as a factor in the control of aphids; although they have been known (Prof. T. H. Parks†) to play a considerable part in some outbreaks (Toxoptera in Kansas during 1909). For these reasons, they have practically escaped attention from a biological standpoint, and most of them have been known systematically but a few years (since 1908).

With the hope of contributing something to the knowledge of the bionomics, life-history, economic importance, and relationship to the aphid complex in general, work was begun on *Aphelinus semiflavus* in the greenhouse insectary of the Ohio State University, Department of Zoology and Entomology, in the fall of 1920, as part of a thesis for the degree of Master of Science in Entomology. This was continued throughout the winter to the middle of May, 1921; when the thesis was written. After graduation in June, part of a series of parthenogenetic generations of the parasite was taken to Oak Lane, Philadelphia, Pennsylvania, where rearing and study was continued at intervals until the time of this writing, February, 1922.

ACKNOWLEDGMENTS.

The writer here wishes to express appreciation for the kind assistance of Dr. Herbert Osborn, who directed the work with many valuable suggestions and criticisms, and to Dr. R. C.

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* Private communication.

† Private communication.

Osburn for suggestions and corrections in manuscript. Many thanks are given to Prof. T. H. Parks for useful suggestions on rearing methods and recording of data; to Dr. C. H. Kennedy for aid in microtechnique and drawing; and to the entire staff of the Department for aid in advice and equipment.

Among those outside the University to whom the writer is especially grateful, are Dr. L. O. Howard, authority on aphis-feeding Aphelinids, who very generously gave of his valuable advice, and assisted greatly in the confirmation of records and determinations; Mr. A. B. Gahan, of the National Museum, for determining the parasites; Mr. T. L. Guyton, of the Pennsylvania Department of Agriculture, for determining the aphids; and Dr. Paul Marchal, director of the Entomological Station, Department of Agriculture, Paris, France, for giving first hand his experience in colonizing *Aphelinus mali* How. in France.

METHODS AND APPARATUS.

Practically all the data included in this paper are from indoor rearing, either in a greenhouse or room. Most of it was carried on in the greenhouse insectary of the Ohio State University, and near a window in room 107 of the Botany and Zoology building. The observations made in Pennsylvania were taken on material grown before an open window in the writer's private room in Oak Lane. That the results thus obtained should vary with outdoor conditions is a fact which must not be overlooked; especially since experience has shown *Aphelinus* to be quite sensitive to slight temperature changes below a certain point.

The temperature in the greenhouse insectary varied from 50 degrees Fahr. on cold winter days, to 100 degrees on warm, sunny days of early fall and late spring. For the greater portion of the time, it remained between 70 and 80 degrees Fahr. The room in the Botany and Zoology Building stayed very close to 70 degrees all the time. No temperature readings were taken for Oak Lane, but here it was very near outdoor temperature during the summer and warm room temperature (70 degrees and above) for the winter.

Light and humidity were not measured.

Those cages which gave the most satisfaction in the matters of light, ventilation, security, and accessibility, were the standard lantern globe cage used in rearing aphids, and a specially designed celluloid cage. The celluloid cage was found to be far superior to the lantern globe in ventilation and its equal in all the other factors. However, both were used with success throughout the work.

Myzus persicæ Sulz., a common aphid on dock and crucifers, was used for a host in practically all the experiments, although several other species were carried along for the purpose of testing the parasite in other hosts. This aphid proved to be quite satisfactory in every way; since it was the natural preferred host of *Aphelinus semiflavus*, reproduced readily throughout the winter on a number of common plants, and was attacked by practically every other aphid parasite. Dock (*Rumex cripus*, and *R. obtusifolius*) was found to be the best host plant for this aphid, and was also very satisfactory from an experimental standpoint; being easily grown, and having large smooth foliage which greatly facilitated observation and handling.

Parasite-free material was obtained by rearing in tight cages.

In all experiments, a few specimens confined in a small, neat cage gave better and more accurate results than many in a large cage. Too many aphids to start with would multiply so rapidly that they would kill the plant before the experiment could be closed, making it necessary to transfer them, which always resulted in loss of material.

For development studies, a number of parasites were confined with parasite-free aphids for a few hours and then removed. A number of these aphids were dissected at intervals to determine the stages reached by the parasite in a given time. These dissections were made in normal salt solution held in a hollow ground slide under a binocular microscope. Very fine sewing needles mounted in matches served as excellent instruments. When the parasites had killed the aphids, they were removed to gelatin capsules marked with the number of the cage and date of removal. These were then filed in small cardboard boxes, by the month, for further reference, in watching their development from then on. These developments in the capsules were checked by cage rearing and found to coincide. Gelatin capsules were made use of as containers for all the material that was retained for future reference.

IDENTITY AND DESCRIPTION.

Aphelinus semiflavus was first described by Howard ('07) as follows:

> *Female.*—Length 1.08 mm.; expanse 1.87 mm.; greatest width of fore wing 0.3 mm. Antennæ short, excluding scape about the length of face; pedicel long, more than three times as long as wide; funicle joints 1 and 2 in length and width and each slightly less than one-third length of pedicel; joint 3 two-thirds length of pedicel and about as wide as its tip; club slightly swollen, ellipsoidal, and about twice the length of pedicel. Eyes faintly hairy. General color black; thorax smooth, shining, scape and pedicel dusky, flagellum pallid, club becoming somewhat dusky at tip; front and middle femora and all tibiæ somewhat dusky; hind femora straw yellow. Abdomen light yellow shaded around margin with brownish. Wings rather short, otherwise normal.
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> *Male.*—Length 0.85 mm.; expanse 1.58 mm.; greatest width of fore wing 0.204 mm. Differs from female in having antennæ nearly uniform brown, scape slightly darker, and in the proportion of third funicle joint and club. Third joint cylindrical, twice as long as pedicel and six times as long as broad; club one-quarter longer than third funicle joint, elongate ovate in shape.

Described from 14 male and female specimens reared by C. P. Gillette, Fort Collins, Colorado, July 15, 19, 1908, from Myzus persicæ, and reared at Washington from the same host sent in by Professor Gillette. The parasitized host turns black.

U. S. N. M. type No. 12,931.

DISTRIBUTION.

Geographical.

There are very few available records on the distribution of *Aphelinus semiflavus*, but these seem to indicate that it is rather wide for the United States, at least. Dr. Howard has kindly furnished the writer with the United States Bureau of Entomology records that he had available, which follow:

Reared from Myzus persicæ Sulz., Fort Collins, Colorado, by C. P. Gillette, July 15, 1908.

Reared from Myzus (new species) on Aguilegia, at Lafayette, Ind., by J. J. Davis.

In addition to these, Webster and Phillips ('12) have published records from St. Anthony Park, Minn., and Mesilla Park, N. Mex. The present work will add Ohio to the States in which *Aphelinus* occurs. So far it has not been found about Philadelphia, Pa., after a summer season of diligent search.

Seasonal.

The data on this point are likewise very scant. Practically all records show that *Aphelinus* appears rather late in the summer and fall. The writer did not find it about Columbus until the first of November, in spite of the fact that he was collecting aphid parasites there from the middle of September on. Mr. T. H. Parks*, who was with Webster and Phillips in Kansas during the work with the "green bug" parasites, is of the openion that *Aphelinus* does not become numerous until late fall.

Winter is probably passed in the pupal stage within the blackened remains of the host, according to the observations of Kurdjumov ('13) working with a similar species in Russia. A few attempts were made to carry it through the winter in hybernation cages outdoors in Columbus, but all failed, even though *Aphidius* confined with them emerged on the first warm days of spring. These attempts were repeated the following fall and winter in Philadelphia with no better success.

As soon as the weather began to moderate in the spring an outdoor wire-screen cage was established over some dock plants (*Rumex obtusifolius*) in which was placed a colony of parasite-free *Myzus persicæ*, together with ten or fifteen *Aphelinus semiflavus*, to note the behavior of the parasite out of doors at this season. Observations began on April 11th and continued every other day until May 13th, and then every few days until May 24th, when the experiment was closed.

On the first night after the cage was established there occurred a slight frost which numbed the parasites for a time, but they became active again as soon as the sun came out. Several warm days followed, with rather cool nights, and then about a week of cool rains followed by more warm days.

Several parasites were observed in the cage among the aphids for three or four days, when they disappeared. On the 25th of April, one live *Aphelinus* was again observed in the cage ovipositing in the aphids. Observations were made on this one intermittently until May 20th. The aphids multiplied rather slowly for the first ten days in the cage and then gradually recovered their normal rate, producing a good supply of young.

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* Private communication.

In spite of the fact that live parasites were confined with these aphids for over a month during a period of rather moderate weather conditions, none of them showed the characteristic blackened appearance of parasitism.

On May 5th, fifteen aphids were dissected and one parasite egg found, which appeared just ready to hatch. Later observations, however, showed no sign of parasitism. On May 20th, more aphids were dissected in which were found three or four well grown larvæ, apparently normal. On the twenty-second, one aphid had turned black. This was the only one of the lot turning by May 24th when the experiment was closed.

While the above observations are rough and incomplete, they more than suggest a considerable influence of weather conditions on the activity and development of *Aphelinus*.

Where conditions are favorable, *Aphelinus* will multiply throughout the year; the generations following each other in cycles of 20 to 30 days, depending largely on temperature.

BIONOMICS OF ADULT.

Emergence.

Emergence takes place through an irregular rounded hole cut on the posterior-dorsal side of the blackened host remains. The fact that the emergence hole is always cut in this one particular spot, is due to the peculiar orientation of the parasite in respect to the host; the main axes of the latter being exactly vice versa to those of the former, which always bring the mouthparts of the parasite in this one position.

Locomotion.

Movement is rather sluggish in Aphelinus compared with other aphid parasites. Unless disturbed, it usually crawls deliberately about among the aphids. At times, however, it was observed to hop from one leaf to another, or from the side of the cage over onto a plant. When stimulated with a needle, it will hop away much like a flea; taking short jumps of two or three inches. Many attempts were made to goad it into sustained flight, but all were unsuccessful. In every case, it would slant downward, even when held several feet above a piece of white paper before a window. The wings are slightly reduced, and probably are not capable of sustaining it in flight at all. On the other hand, the legs are well developed.

The above evidence would tend to discredit *Aphelinus* where rapidity of dispersion was a prerequisite for efficiency, but Mr. H. S. Smith and Harold Compere ('20) have pointed out in their work with *Aphycus lounsburyi*, an imported parasite of the black scale in California, that this is a trait in the parasite's favor where it is for local distribution by man.

Reaction to Light.

The adult *Aphelinus* is slightly positive to light, but it does not become quiescent in darkness, as shown by several experiments to determine the effect of light on oviposition, which will be taken up in detail under that heading.

Oviposition.

When the attention of *Aphelinus* is directed toward an aphid for oviposition, it moves with extreme precaution and deliberation; approaching very slowly and steadily, swaying from side to side and feeling forward with the antennæ. Just before the antennæ touch (in some cases they do touch), it halts its forward progress, sizes the situation up carefully from short range, obliques slightly, turning the head toward the aphid with a last parting look as if to make sure of the aim, position, etc., and then suddenly faces about, rising well up on the legs, thrusts the ovipositor out and downward with three or four quick backward strokes toward the victim. In the majority of cases, these miss the mark, either by the aphid moving or through poor aim. Usually they fall short and the point of the ovipositor is brought down on the substratum on which the aphid rests. If the host is in an advanced stage, the parasite may have difficulty in piercing the integument. In either case after about three or four thrusts, it will turn and repeat the act, or crawl away in search of a more favorable victim. However, if successful, it remains in position, standing well up on the legs, the ovipositor thrusts out and downward, with just the tip inserted in the host. (Plate I, Fig. 2). This position is often maintained for several minutes. In fact, some were observed to last as long as fifteen minutes, and repeated twice in succession for a like period without depositing a single egg.

In the majority of instances, the aphid appears undisturbed while oviposition is going on. This is especially true of the younger stages. However, there are times when the slightest touch with the antennæ or a prick with the ovipositor will cause them to kick up and make off. If this happens when the ovipositor is fastened in one of the larger stages, it drags the parasite with it. If the host is smaller, however, the parasite is able to master it and keep it in place in spite of its struggles. This is done by the parasite standing well up on its legs and holding up the victim slightly so that it cannot get a firm foothold on the substratum. The ovipositor is held in place during the struggle by the presence of three retractile barbs near the tip. These function so efficiently that the parasite itself often has difficulty in getting free, often having to brace the hind legs against the aphid and give several vigorous pulls before it is withdrawn. At times, the ovipositor may be fixed so firmly in place that it permits a larger host to drag the parasite about so violently that injury results. Several times *Aphelinus* has been observed in a crippled condition after getting free from one of these encounters. In this condition, the ovipositor remains extruded, the parasite not having the power to retract the abdominal segments that bring it back in position, and the individual goes stumbling off with head down and abdomen elevated until it topples over apparently dead.

The ovipositor is usually inserted on the dorsal surface of the host's abdomen, but almost any other part of the body may be chosen, depending on the point of approach. Many times it has been observed on the head between the antennæ, and among *Macrosiphum pisi* on clover, a large species that stands at a considerable angle from the plant, well up on its long legs, the parasite was observed to attack it from beneath, elevating the ovipositor well up and making contact with the ventral surface of the abdomen.

Stage of Host Preferred.—A distinct preference was early shown for the younger stages of aphids. In order to determine this more exactly, several experiments were planned and carried out. Some difficulty, however, was encountered in eliminating a number of factors that might alter a true expression of this preference. These factors were the variation in numbers of the different stages available for oviposition; the high mortality of the first and second stage nymphs after being parasitized; and the difficulty of handling large numbers of the various stages of aphids necessary to obtain accurate results.

At first a large number of parasites were placed with a greater number of aphids, in the different stages, for a short time and then removed. An equal number of aphids, representing the different stages, were then isolated and the parasites allowed to develop in these until they showed externally. These parasitized individuals were then counted and the percentage taken to indicate the preference of the parasite for a given stage. (See Table I.).

TABLE I.

Showing the Percent of Parasitism in the Various Instars of the Aphid Host, Reared Through Until It Appeared.

No. Aphids Used	Instars	No. Parasitized	Percent.
100	1–2	26	26
100	2–3	16	16
75	4–adult	5	6.6

This method was unsatisfactory, as it did not account for the death of a large number of the smaller stages, which would lower the percentage considerably for that group. It also did not necessarily provide an equal number of the various stages, either at the beginning or the end, to eliminate chance. Then finally the separating and keeping the aphids in different cages for any length of time always made possible the death and escape of many specimens that could not be accounted for.

To get around these difficulties, the following modifications were introduced: As nearly equal and smaller numbers of the different stages were placed together with a number of parasites for a day or so and then all were dissected. The percent parasitized in the various groups, as indicated by the presence of the parasite's egg, showed fairly accurately the preference for that particular stage. Three separate lots were thus treated with the results shown in Table II.

The extreme rarity of parasitism in the adult aphids was clearly demonstrated in the experiments to determine the effect of parasitism on the production of young, in which it was necessary to bring about a parasitized condition in the adult after she had started to produce young. Out of many trials to bring this about, but three were successful; notwithstanding the fact that several parasites were confined for days with the adult aphids time and again.

It is believed that several factors operate here to determine this preference for the younger stages of the host; namely (1) size, it being easier to ovipost in a small aphid than a large one, due to position alone; (2) irritability, the large aphids are more irritable than the small nymphs, which often renders oviposition impossible; and (3) toughness of the integument which makes it difficult for the ovipositor to penetrate.

Table II.

Showing the Percent of Parasitism in the Various Instars, Dissected Immediately After the Parasites Were Removed.

Approx. Instar	No. Dissected			No. Parasitized			Percent Parasitized		
	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3
1–2	90	105	42	54	58	19	60	55.7	45.2
3–4	161	84	57	66	26	20	41	31	35
4–5	62	61	19	10	4	1	16	6.9	5.2

Number of Eggs per Host.—In more than 3,000 separate dissections for egg counts, etc., there were only two or three cases where more than one egg was deposited in a single host. These few exceptions occurred only where a number of parasites were confined with a few aphids for several days, and even then no more than two eggs were ever found in a single host. In some of these trials a parasitism of 100 percent was obtained for 20 first to third instar nymphs confined with one parasite for a single day of twelve hours. Instances were observed several times where parasites apparently oviposited in hosts already parasitized, even to the blackened condition; but in no case did subsequent dissection show that an egg was deposited. *Aphelinus* has also been observed to return several times to a single host, but here, likewise, only a single egg is left, or in many cases none at all.

The above observations seem to indicate that *Aphelinus* places but one egg in a host, but that it is incapable of determining whether a given host harbors a parasite already until the ovipositor is inserted. The above habit is decidedly in its favor when its efficiency as a parasite is considered in contrast to some of the more wasteful species like *Aphidius*, which generally places a number of eggs in a single host, but only one of the resulting larvæ matures.

Number of Eggs Laid per Day and Night.—To determine the number of eggs laid per day and night over the period of egg production, experiments were carried out with a single *Aphelinus* confined with a given number of nymphs from the first to the third instar. Dissections were made on these both in the evening and morning, and a fresh supply of parasite-free aphids placed in the cage for the parasite to oviposit in for the succeeding period. During the night, the cages were kept in a dark chamber so that practically absolute darkness prevailed until the time came to change to light. As nearly equal periods of light and darkness were obtained as was possible; likewise, other factors, such as temperature and humidity, were fairly uniform. All experiments were carried out in room 107 of the Botany and Zoology Building, in a temperature of from 70 to 75 degrees.

Owing to the extreme minuteness of the specimens dealt with, considerable difficulty was experienced in carrying a single parasite through its total life without its escaping or being accidently killed in handling. This was so great that only one specimen went through its total period of egg production to a natural death. Two others were carried for seventeen and eighteen days respectively before they escaped or were accidentally killed. The results of these experiments appear graphically in Figure 1.

Feeding.

It is quite evident from observations made that the commonest means of sustaining life in the adult *Aphelinus* is by its habit of feeding at the puncture holes made by the ovipositor in the young aphids.

This habit is not restricted to *Aphelinus* alone, but seems to be rather common among chalcid parasites in general. The records with which the writer is familiar date from Howard ('08), where he quotes Dr. Marchal's observations on this habit in the parasite *Tetrastichus xanthomelænæ* Rond, on the eggs of the elm leaf beetle *Galerucella luteola*. Later Howard ('10) in a more general article on this habit among the Chalcidoidea, again refers to Marchal's observations on *Tetrastichus*, in addition to some similar observations on *Aphelinus mytilaspidis* in *Aspidiotus ostreæformis*, along with several others; namely, Dr. H. T. Fernald on *Tetrastichus asparagi*, feeding on the eggs of the asparagus beetle (*Crioceris asparagi*), and Mr. J. G. Sanders concerning *Aphelinus fuscipennis* on *Aspidiotus* rapax. Mr. H. J. Quayle ('10) also refers to a similar habit as occurring rarely in *Aphelinus diaspidis*, parasite of the red or orange scale (*Chrysomphalus aurantii*) in California. He also observed this species to feed on honey dew, plant juices, and fruit. Mr. L. P. Rockwood ('17) published for the first time observations on this habit in *Aphelinus lapisligni* How., feeding at the

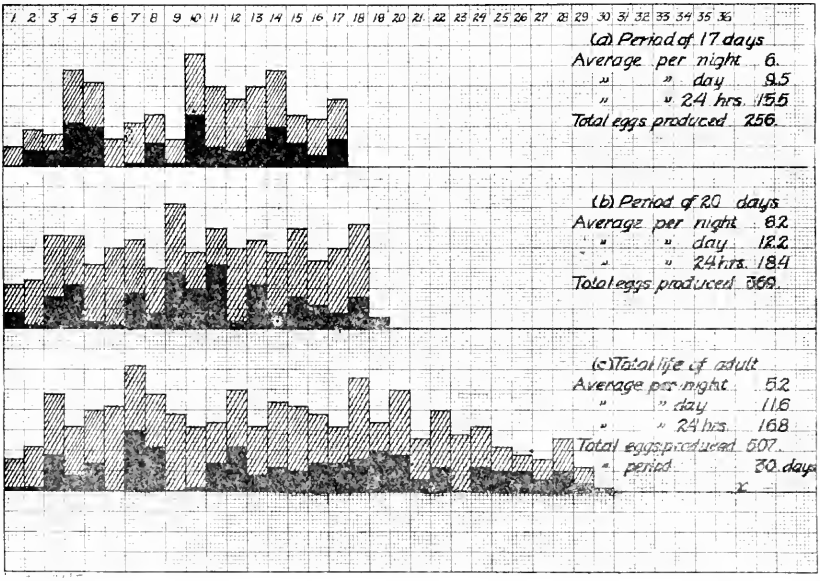

Fig. 1. *Number of eggs deposited by a single Aphelinus semiflavus per day and night for a given period.* Black equals night, cross lines equals day; large squares on abscissa equal 24 hours; small squares on ordinate equals one egg; "x" equals point where natural death occurred.

puncture holes in *Aphis bakeri*, in which the actions are described in some detail.

A number of the above cited observations have been verified, by the writer, on *Aphelinus semiflavus*, and additional data have been secured on this interesting feeding habit.

These parasites confined in glass vials or other receptacles without food or water were noticed to live but two or three days at most; while those among aphids lived a much longer time (two weeks or more). This species had also been observed feeding at the puncture holes made by the ovipositor in aphids. In addition to this aphid-feeding habit, the writer was interested to know whether they fed on any other substance, and if so, how long they would live on the various kinds of food that might be available. This point was thought to have considerable bearing on methods of handling and transporting species to be used in an economic way for the suppression of injurious forms.

Several experiments were undertaken to test out the effect of various foods on the length of life of adult Aphelini. Specimens emerging at the same time were placed in cages as follows: One lot on dock (*Rumex obtusifolius*) only, in a lantern globe cage; another with four or five large aphids not yet producing young; still another on a dock plant to which leaves covered with honey-dew were added every other day; and lastly, a lot on a plant with honey solution added every day. All were confined in lantern globe cages with growing dock plants in room 107 of the Botany and Zoology Building. The results appear in Table III.

Some careful observations were made on *Aphelinus semiflavus* in the act of feeding at the puncture holes made by its ovipositor in aphid nymphs. To confine the specimens so that they could be easily observed under a binocular microscope, two hollow ground slides were used with the aphids and parasite in the space between them on a bit of leaf. Four or five 2-instar nymphs were thus enclosed with one female *Aphelinus*. Oviposition began immediately after they were placed together, and was repeated several times in the same aphid, after which the victim was noticed to droop down in a sickly condition. In this state the parasite approached and carefully examined the aphid with its antennæ. Being apparently satisfied, it placed its forefeet on the victim's back and its mouthparts to the puncture.

This position was then held for several minutes without moving, during which the body of the aphid was noticed to slowly collapse. After it was apparently sucked dry, *Aphelinus* would withdraw and search out another victim where the same maneuvers were repeated. Three small nymphs were thus fed upon in half an hour, after which the parasite's abdomen appeared quite distended with their contents.

These dead aphids were later dissected, and it was found that *Aphelinus* had deposited an egg in each. This would seem to indicate that oviposition was the primary object in puncturing a host, and that feeding was a secondary, acquired habit.

TABLE III.

Effect of Different Food, Accessible, on Length of Life in the Adult Parasites.

Food	Number of Parasites	Length of Life
Dock plant	3	3 days
4th instar aphids	3	4 days
Honey-dew (on leaves)	3	11–12 days
Honey solution (fresh)	1	39 days

However, with this habit of feeding, the parasite defeats its primary purpose by killing the host and preventing the development of the egg immediately after it is deposited.

Observations made in the course of other experiments show that a single parasite ordinarily kills, in the above manner, from three to five of the smaller instars per day. The very young stages are almost always preferred, although it has been noticed to feed on a third or fourth instar nymph. That the older stages are seldom if ever attacked, has been demonstrated in a number of instances where *Aphelinus* was confined with adult aphids for various purposes. The parasite not only failed to oviposit in these adults, but actually died with them for want of food when the adult aphids did not produce young for it to feed on. In all cases the aphid is very much weakened so as to offer practically no resistance, before the parasite will attempt to feed. While the feeding is going on, the aphid remains slumped down apparently oblivious to the slow ebbing away of its life blood, the only movement being a slight wave of a leg or antenna.

Length of Adult Stage.

The length of life in the adult has been observed to vary according to the kind of food available. Temperature also is undoubtedly an important factor, but no accurate experiments have been attempted to show how it operates.

The effect of the different kinds of food on the length of life is shown in Table III, and may be briefly summarized as follows: Confined without food, on plants alone, among older aphids on plants, or in small receptacles, death ensues in less than four days; on honey dew they live for twelve days; and one specimen was kept alive for thirty-nine days on honey solution in distilled water, given fresh every day until it finally escaped. There is reason to believe that they will live much longer on this. The only one carried through to normal death on aphids, lived thirty-six days; producing eggs for thirty of these days.

REPRODUCTION AND DEVELOPMENT.

Method.

The prevailing method of reproduction in *Aphelinus semiflavus*, as well as in a number of other chalcid parasites, is by parthenogenesis. Seventeen successive generations have thus far been reared parthenogenetically, and there is every reason to expect many more to follow indefinitely; since the last offspring appear as vigorous as the first.

Proportion of Sexes.

Males are quite rare in this species. Out of more than 900 individuals examined from the different generations throughout the series of parthenogenetic generations, but seven males were found. These were scattered more or less irregularly through the series as shown in Table IV. It is quite possible that males might have appeared from time to time in other rearings and passed unnoticed, due to the difficulty of distinguishing the sexes without a microscope. However, throughout all the observations, of either living or dead material, males were encountered but one other time, when three were taken from Cage 48a3 on March 2, 1921. One of these was confined with females among some aphids on a dock leaf in a small vial, and copulation was observed. No observations were made on mated females to determine whether mating had any effect on the proportion of sexes and number of offspring produced. This must be left for later investigation.

TABLE IV.

Sample Counts from a Series of Parthenogenetic Generations Showing Proportion of Sexes.

Generation.....	a_1	b_1	c_1	d_2	e_1	f_1	g_2	h_1	i_2	j_2	k_1	l_1	m_2	n_1	o_1	p_1	q_2
Date...........	3-6 1921	3-22 1921	4-3 1921	5-4 1921	5-23 1921	6-7 1921	6-23 1921	6-29 1921	8-11 1921	9-1 1921	9-24 1921	9-20 1921	10-30 1921	11-19 1921	11-27 1921	12-13 1921	1-30 1922
No. Females...	66	38	61	135	55	59	15	8	132	113	81	6	74	57	1	12	8
No. Males......	0	0	0	3	0	0	0	0	0	1	3	0	0	0	0	0	0

Some of the Encyrtidæ, a family of scale parasites, closely related to the Eulophidæ, produce but few males or none at all. In other species of the genus *Aphelinus*, feeding on aphids, the males are not known.

The production of females parthenogentically that are capable of producing more females in the same manner, for an indefinite number of generations, is a very valuable asset to a parasite when it is to be established in new territory. By this method of reproduction the chances of its increase are greatly enhanced. Likewise, it is less liable to die out through reduction in numbers and consequent scattering of individuals that would reduce the chances of mating where this was important for the perpetuation of the race.

The Egg.

Description.—The egg is elongate ovate, and slightly bent in the middle, with dimensions of .21 x .05 mm. The anterior end is slightly more rounded than the posterior, which tapers bluntly to a point. At the anterior end, there also appears a small nipple-like micropyle that projects just far enough from the surface to be seen with a high power compound microscope. The color, in reflected light, is a very light cream-white; darker in transmitted light. The corion is very thin and transparent; showing the finely granular structure of the contents, which is homogeneous throughout for a few hours after the egg is laid. Soon development begins to appear by the characteristic form of the growing embryo. At the end of twenty-four hours the egg clears up slightly, except for certain parts of the embryo, which show darker in the form of two blotches; the one in the anterior portion of the egg having a long and wavy form which bends around like a hook near the end of the egg; the other in the posterior portion is more rounded. Both of these blotches finally join together by the growth of the mesenteron, shown by two faint lines. When the egg is forty-six to forty-eight hours old, it becomes still more transparent, and only one elliptical dark spot appears near the center. It is now almost ready to hatch. (See Figs. 3, 4, and 5, Plate I.).

Position in Host.—The egg floats loose in the hæmocœl of the host, where it may be seen on dissection under the high-power of a binocular microscope. It is quite large in size compared with the size of the adult.

Length of Stage.—The period of time spent in the egg stage is very near three days (72 hours) for all the observations.

Number Laid.—The only actual count made of the number of eggs laid by a single individual in the course of its life, gave 507. (Fig. 1). Other partial counts would lead one to believe that this is a good high average. The conditions under which the eggs were deposited may be considered almost optimum, since the parasite was closely confined with a number of parasite-free aphids of the most desirable stage. It is difficult to make an estimate of what the total number would be under more natural conditions out of doors, but it is probably much less than the actual counts indicate for caged material. From the number of blackened aphids obtained from the different cages, one might estimate the total number parasitized by one adult female to be around 200.

Like many other parasitic Hymenoptera, there are only a few mature eggs in the ovarian tubes at a time; about ten for *Aphelinus*. The other eggs mature from day to day in such numbers as required, which is probably regulated by some external stimulus, like the presence of a large number of hosts.

Larva.

Description.—The larva when first hatched has practically the same size and form as the egg, but slightly shorter and broader. As growth proceeds the anterior and middle segments enlarge to accommodate the increasing mesenteron, giving it at first a spindle form and later a distinct top shape; the head forming a knob on the broad rounded anterior end, and the posterior tapering to a rounded point. When the larva reaches maturity it is contracted more in a longitudinal direction, becoming almost globular in general shape. (Fig. 7, Plate I).

In the younger stages the color is almost absent, except the dark mesenteron which stands out against the general transparency. Later on the accumulating fat body lends a light yellow color to the larva.

The segmentation of the larva is rather obscure, but with careful search thirteen may be counted. The head is distinct, supported by a visible tentorium, and bearing a mouth opening in the anterior ventral portion. This mouth is armed with two sharp dark mandibles which are situated well back in the cavity, but are capable of protrusion sufficient for grasping purposes. A peculiar botryoidal structure may be also observed covering the front and vertex. (Fig. 8, Plate I). This is probably a group of sensory organs. The entire digestive tract may be traced from mouth to anus in transmitted light; though the fore and hind guts-are indistinct. Several other internal organs were slightly visible, but no attempt was made to identify them. Spiracles are observable on segments five to nine inclusive, but could not be seen on any of the others. Small tracheæ lead off from these, but it was not determined whether they function or not.

Position in Host.—During most of the growing period the larva occupies no definite position in the host, but moves freely about in the fluid of the body cavity. However, when it has devoured most of the internal organs of the host and has become large enough to fill the abdominal cavity it assumes a position with its primary axes similar to those of the host. Just before pupation this position is exactly reversed, so that the primary axes of the parasite are opposite to those of the host, both anterior-posteriorly and dorso-ventrally.

Length of Stage.—The larval period varies from about six to eleven days, or even longer in some cases where the temperature is low. The usual time from egg deposition until the aphid host turned black, was nine to ten days. Pupation began within one or two days after the host turned black, and by the end of three days the last larval skin was cast and the full pupal form assumed.

It was found that it took two days longer for the larva to kill and turn black an adult aphid than it did for a third instar nymph, and one day longer for a first instar nymph than for a third instar. This would seem to indicate that the medium instars furnished optimum conditions for the development of the larva, where other factors were equal.

Pupa.

Description.—The pupa is characteristic of the Hymenoptera in general, *i. e.*, of a form similar to the adult, with rudimentary wings, and large turgid legs and antennæ lying near the body on the ventral side, and enclosed in transparent sheaths. When first formed the pupa is almost transparent or very light yellow throughout. Soon the eyes turn to a reddish brown and the light yellow deepens with age until the colors of the adult are reached at maturity.

Meconia.—As soon as the pupa begins to take form, or just before it sheds the last larval skin, it voids several brown bodies of an oval shape. These are the characteristic meconia of the parasitic Hymenoptera, and represent the total, larval excrement that has accumulated throughout the period and discharged at this time.

Position.—The position of the pupa with reference to the host is exactly opposite to the primary axes of the latter, the same as described for the mature larva. This places the mouth parts of the adult *Aphelinus* in a position to gnaw out the emergence hole on the posterior-dorsal surface of the blackened host remains.

Length of Stage.—The average length of the pupal stage is seven to eight days, but it may vary between five and fifteen days, or even longer under adverse conditions. There is every reason to believe that it passes the winter in this stage.

Effect of Parasite on Host.

On Internal Structures.—As soon as the young *Aphelinus* larva hatches, it begins feeding on the fat body and developing young of the host. Within three or four days after hatching nearly all the young aphids within the mother are destroyed. The feeding continues on the other structures, until nothing is left, when the parasite larva approaches maturity, but the digestive tract. This is in common with the habits of other parasitic Hymenoptera larva which spare the vital organs of the host until the very last.

The larva of Aphelinus is armed with well developed mandibles, which, however, do not project out of the mouth as in the larva of the Braconid parasite, *Aphidius;* but seem situated back in the mouth cavity where they are less effective in tearing up host tissue. There is no gathering of bunches of fat globules in a host parasitized by *Aphelinus*, as in one harboring *Aphidius*, which would indicate that the fat cells are not broken down. However, many bits of tissue and separate cells may be observed floating promiscuously around in the body fluids of a host parasitized by *Aphelinus*.

On External Appearance.—The first external appearance of parasitism is a change in color of the host from green to light cream. Then a honey-colored spot appears in the abdomen, which is the darker mesenteron of the larval parasite within. This light color of the host deepens into a yellow or light amber in another day, and by the following day begins to turn gray. Within a very few hours after graying begins, the aphid is coal-black, except for the head and appendages, which are transparent. Death occurs during this last darkening. Just before death the aphid spreads out its legs in symmetrical form and firmly grasps the plant on which it rests. This tends to make them adhere to the plant after death; still, they are further secured by some form of silk secretion through the ventral wall. No detailed observations were made on this act, but it is evident that no hole is cut through, as in *Aphidius*. Perhaps only a very small puncture is made and the silk forced through it. The amount is very small, at most, and in some cases there is not enough to detect; nevertheless, the black aphid remains adhere quite firmly to the substratum.

On Production of Young.—Several experiments were undertaken to determine the effect of parasitism in the various instars on their subsequent maturity and production of young. An equal number of parasites were confined with separate lots of different ages and instars of aphids for a day and then removed. The aphids were observed until they showed parasitism and died. One nymph, parasitized on the day it was born, carried the parasite through to maturity, but did not mature itself, or produce any young. Three nymphs, parasitized in the second instar, produced but one young, which was doubtfully from one of these nymphs, since another unparasitized one occurred in the same cage. Nine second instar nymphs matured and produced but two young at the end of eleven days from birth. Seven nymphs, parasitized in the third instar, matured and produced sixteen young before succumbing to the parasite. With the larger stages, parasitism was so rare that no data were obtained.

It appears from these experiments that those aphids parasitized in the second instar seldom mature and produce young; while those parasitized in the third instar may mature and produce several young before they are killed.

In the few cases where adult aphids were parasitized after they had begun to produce young, the production continued for six days from the time the parasite's egg was deposited. During this time two females produced twenty-five young. Allowing three days for the egg of *Aphelinus* to hatch, it will be seen (Fig. 2, curve "d") that the decline in production of young began shortly after the egg hatched. Production ceased altogether two days before the death of the host.

Aphelinus may also disturb the production of young in aphids by worrying or exciting the viviparous females. This is shown in Figure 2, curves a, b, and d, between the points x and x_1 where the parasites were introduced and removed. In every case a marked drop occurs in the production. However, as soon as a few young are born, the parasite's attention is directed to them so that the adults may go on producing others unmolested. Here is where the preference of *Aphelinus* for the younger stages of the host is of marked significance as a factor in their control, since it does not attack at the source of production, the adult female. This may account for the fact that *Aphelinus* is much slower than *Aphidius* in exterminating a colony of aphids with which they are confined.

Effect of Host on Parasite.

As in common with most parasitic Hymenoptera, there is a great variation in size of adults according to food supply or size of host. This was more than double in *Aphelinus*, or from .35 mm. to .75 mm. in length. The extremely small specimens were apparently sterile, for several trials on parasite-free nymphs failed to get them to reproduce, or even lay eggs. An attempt at oviposition was noticed in one case, but the parasite was unable to extrude the ovipositor its full length.

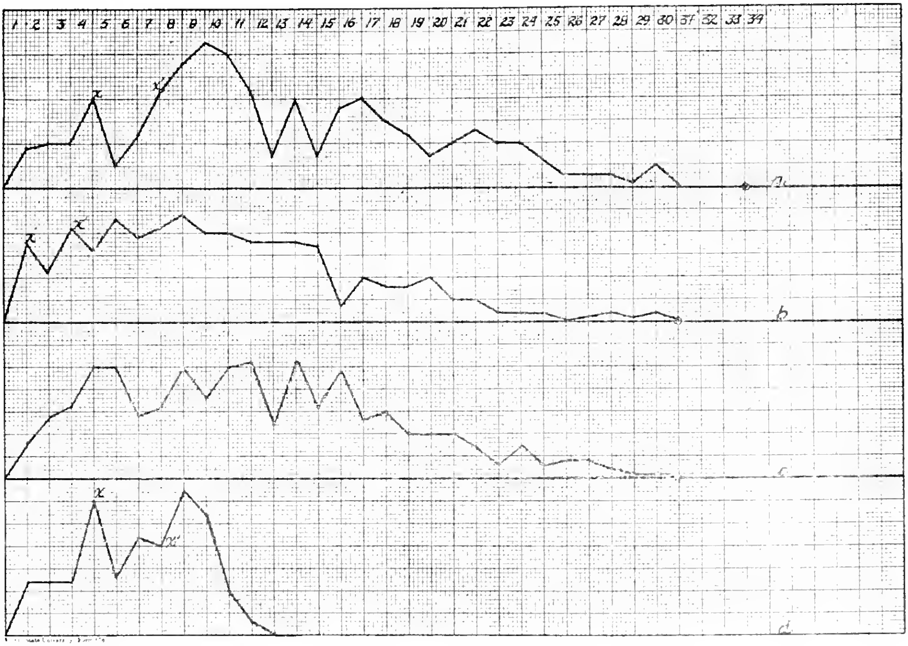

Fig. 2. *A series of curves showing the effect of the parasite Aphelinus semiflavus on the production of young in adult viviparous Myzus persicæ.* a. Average daily production of young in six females for the average total period of production, with *Aphelinus* but unparasitized (note drop in curve between x and x_1 when parasites were introduced, showing effect of the presence of *Aphelinus* on production of young); *b.* average daily production of young in ten females for the average total period of production with *Aphelinus* but unparasitized. (note drop between x and x_1 as in *a*); c. average daily production of young in ten females free from parasites; d. average daily production of young in two females for the average total period of production before and after parasitism. The parasites were introduced at the point x and removed at x_1. Death from parasitism occurred at the end of he curve.

COHOSTS.

Previous records give *Myzus persicæ* Sulz., *Aphis gossypii*(?) Glover, *Aphis maidis* Fitch, and *Chaitophorus viminalis* Mon., as hosts for *Aphelinus semiflavus.* The writer can add to this list from his own rearings, the following: *Macrosiphum pisi* Kalt., *M. granarium* Kirby, *M. Sanborni* Gillett, rarely, and *Anuraphis viburnicola* Gillett.

Myzus persicæ, from which most of the field records come, seems to be the preferred host, although it took to *Macrosiphum granarium* and *Anuraphis viburnicola* quite as readily in captivity. *Macrosiphum pisi* was not parasitized very heavily, due, perhaps to its long legs and large size, and irritability. *Macrosiphum sanborni* escaped almost entirely for no apparent reason. They were only rarely attacked even when confined in a cage with a number of parasites, and a colony went through the winter in the greenhouse among many parasites with but a scarce eight or ten being parasitized.

Several attempts were made to rear *Aphelinus* in *Aphis rumicis,* another common dock aphid, but all were unsuccessful. The parasite would oviposit in them freely, and subsequent dissection showed that the eggs would hatch and the larva become nearly half grown, in some cases; but they would always die before reaching maturity. In most cases death occurred shortly after the egg hatched.

INTERRELATIONS WITH APHIDIUS.

Considerable importance has been attached to the interrelations of primary parasites in a single host, since the discovery by Pemberton and Willard (18) of the disastrous results of the interrelations of two primary fruit fly parasites imported to the Hawaiian Islands.

From what is known of the two groups of primary aphid parasites, there seems to be no question about the superiority of *Aphidius* over *Aphelinus* as a controlling factor for aphids. It not only appears earlier in the season, but lays more eggs in a shorter time, is more vigorous in its actions, is not confined so closely to the younger aphids, and has a much greater dispersal than *Aphelinus.* It was, therefore, both interesting and important to determine to what extent these two occurred in the same host, and the ultimate outcome of such occurrence.

Observations on colonies of aphids in the open greenhouse among both *Aphidius* and *Aphelinus* showed that parasitism of a single host by both parasites was rare at best, if not entierly absent. In fact, it was often difficult to bring this about when they were confined in a small cage. However, when they were put in and taken out separately, the one before the other, results were different. *Aphidius* would parasitize practically every aphid in a small colony, and all the eggs that *Aphelinus* would deposit later, which was always considerably less than *Aphidius* for a given period, would be in the same host with one or more *Aphidius* eggs or larvæ.

When *Aphidius* was placed with a colony of aphids a day ahead of *Aphelinus* and removed before *Aphelinus* was introduced, a heavy parasitism by both resulted. But in practically every case, the *Aphelinus* eggs failed to hatch. The conditions were then reversed, and *Aphelinus* was given a day's start. In this case *Aphelinus* hatched and began development in the usual way, but they did not interfere in the least with *Aphidius* which came along later. This very efficient parasite emerged from its membraneous cover in the normal manner and within a day or two the small *Aphelinus* larva would die. This happened even when the *Aphelinus* larva was allowed several days the advantage over *Aphidius* and was quite large when the latter hatched.

It was, therefore, practically established that for the younger instars, at least, *Aphidius* would always dominate, regardless of whether it came before or after *Aphelinus* in the same host; and that *Aphelinus*, coming after *Aphidius* for a day, would never hatch. In fact, the egg would never begin development as shown in the characteristic change in appearance (Plate I, Fig. 3, 4 and 5.)

Possible Ways by Which Aphidius May Cause the Death of Aphelinus.

Just how the death of *Aphelinus* is brought about still remains a mystery that will only be solved by more careful investigation. Several theories are suggested to explain it, but all of them require refined methods to prove. They are given here for what they are worth.

Cannibalism.—Aphidius is much better armed with mandibles and a spiny body, than *Aphelinus*, and is also more active. It might, therefore, be expected to kill *Aphelinus* by feeding directly on it or injuring it fatally by striking against it in the host. Yet, in the many cases that were examined, *Aphidius* was never found feeding on *Aphelinus*, nor did there ever appear evidence of mutilation in the dead larvæ. In each case, *Aphelinus* simply stopped movement and turned darker in color, in which condition it remained until it finally shriveled up and disintegrated.

Starvation.—This theory does not carry much weight when we consider the abundant supply of food present at the time of death.

Toxic Substance.—It is quite possible that something of this nature may be thrown off by *Aphidius* that has an injurious effect on *Aphelinus*, but it is difficult to prove.

Lack of Oxygen.—Our knowledge of respiration in this group of parasites is still very meager, so it is scarcely possible to say just how the above condition might effect the parasites. It appears that both derive their oxygen from the blood of the host, in which they float, and it is also possible that *Aphidius*, being the more active of the two and better adapted for breathing might get around and monopolize it; though it is doubtful if this could be reduced low enough to kill *Aphelinus* and not work permanent injury on *Aphidius*.

Economic Importance.

While the above theories are of considerable importance from a biological standpoint, it is sufficient for economic purposes simply to know which of the two parasites will dominate when the two come together. This the writer has shown. Since *Aphidius* is the more efficient one in every respect, there need be little fear over the fact that it will kill *Aphelinus*, since this efficiency will in no way be lessened where they accidentally come together. The aphids that *Aphelinus* parasitized would not interfere with *Aphidius*, and would be so many more dead aphids in addition to those killed by *Aphidius*.

SECONDARY PARASITES.

Throughout most of the winter of 1921–22, at Columbus, Ohio, very few secondary parasites appeared to infest *Aphelinus* in the greenhouse insectary. But by February, two species began to appear in from ten to twenty percent of the specimens taken in the open greenhouse. One was determined by Mr. Gahan of the United States National Museum, as *Asaphes* (*Megorismus*) *americana* Gir., and the other by Mr. Rowher, also of the Museum, as *Alloxysta* sp., a Figitid resembling *Charips* (*Allottria*).

In the fall of 1921, another secondary was reared from a new species of *Aphelinus* on a juniper aphid near Philadelphia, Pennsylvania, which likewise proved to be a secondary of *Aphelinus semiflavus.* This was determined by Mr. Gahan as *Aphidencyrtus aphidiphagus* Ashm.

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EXPLANATION OF PLATE.

Fig. 1. Adult female *Aphelinus semiflavus* with male antenna and genitalia in insert.

Fig. 2. Female *Aphelinus* ovipositing in aphid nymph.

Fig. 3. Egg less than five hours old.

Fig. 4. Egg twenty-four to twenty-eight hours old.

Fig. 5. Egg forty-six to forty-eight hours old.

Fig. 6. Small larva just hatched.

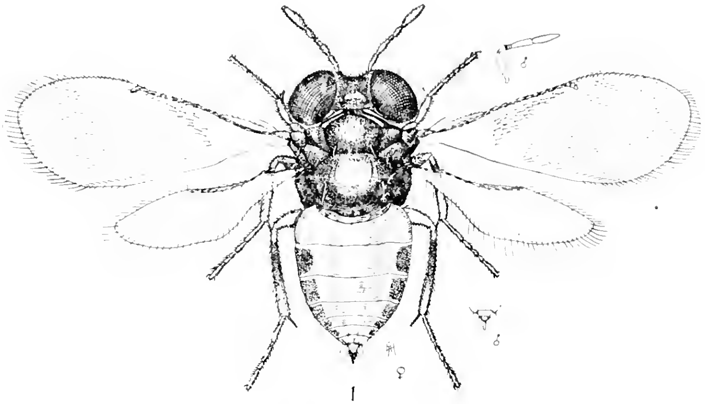
Fig. 7. Lateral view of full grown larva, just before pupation.

Fig. 8. Front view of larval head, greatly enlarged.

All figures, except Figure 8, are drawn approximately to the same scale, enlarged thirty-three and a third times.

Bionomics of Alphelinus Semiflavus
E. A. Hartley

PLATE I.



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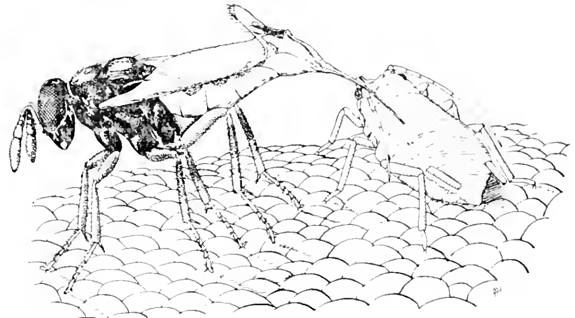

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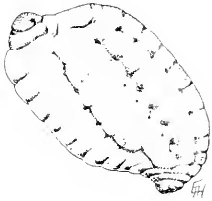

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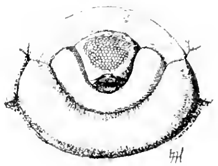

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