PROCEEDINGS

OF THE

Indiana Academy of Science

1910

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EDITOR . . . . L. J. RETTGER

INDIANAPOLIS, IND.
1911

INDIANAPOLIS
WM. B. BURFORD, PRINTER
1911

THE STATE OF INDIANA,

EXECUTIVE DEPARTMENT,

March 26, 1911.

Received by the Governor, examined and referred to the Auditor of State for verification of the financial statement.

OFFICE OF AUDITOR OF STATE,

INDIANAPOLIS, May 5, 1911.

The within report, so far as the same relates to moneys drawn from the State Treasury, has been examined and found correct.

W. H. O'BRIEN,

Auditor of State.

MAY 5, 1911.

Returned by the Auditor of State, with above certificate, and transmitted to Secretary of State for publication, upon the order of the Board of Commissioners of Public Printing and Binding.

MARK THISTLETHWAITE,

Secretary to the Governor.

Filed in the office of the Secretary of State of the State of Indiana, May 5, 1911.

L. G. ELLINGHAM,

Secretary of State.

Received the within report and delivered to the printer May 5, 1911.

ED D. DONNELL,

Clerk Printing Board.

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AN ACT TO PROVIDE FOR THE PUBLICATION OF THE REPORTS AND PAPERS OF THE INDIANA ACADEMY OF SCIENCE.

[Approved March 11, 1895.]

WHEREAS, The Indiana Academy of Science, a chartered scientific association, has embodied in its constitution a provision that it will, upon the request of the Governor, or of the several departments of the State government, through the Governor, and through its council as an advisory board, assist in the direction and execution of any investigation within its province, without pecuniary gain to the Academy, provided only that the necessary expenses of such investigation are borne by the State; and,

WHEREAS, The reports of the meetings of said Academy, with the several papers read before it, have very great educational, industrial and economic value, and should be preserved in permanent form; and,

WHEREAS, The Constitution of the State makes it the duty of the General Assembly to encourage by all suitable means intellectual, scientific and agricultural improvement; therefore,

SECTION 1. *Be it enacted by the General Assembly of the State of Indiana,* That hereafter the annual reports of the meetings of the Indiana Academy of Science, beginning with the report for the year 1894, including all papers of scientific or economic value, presented at such meetings, after they shall have been edited and prepared for publication as hereinafter provided, shall be published by and under the direction of the Commissioners of Public Printing and Binding.

SEC. 2. Said reports shall be edited and prepared for publication without expense to the State, by a corps of editors to be selected and appointed by the Indiana Academy of Science, who shall not, by reason of such service, have any claim against the State for compensation. The form, style of binding, paper, typography and manner and extent of illustration of such reports shall be determined by the editors, subject to the approval of the Commissioners of Public Printing and Stationery. Not less than 1,500 nor more than 3,000 copies of each of said reports shall be published, the size of the edition within said limits to be determined by the concurrent action of the editors and the Commissioners of Public Printing and Stationery: *Provided*, That not to exceed six hundred dollars ($600) shall be expended for such publication in any one year, and not to extend beyond 1896: *Provided*, That no sums shall be deemed to be appropriated for the year 1894.

Sec. 3. All except three hundred copies of each volume of said reports shall be placed in the custody of the State Librarian, who shall furnish one copy thereof to each public library in the State, one copy to each university, college or normal school in the State, one copy to each high school in the State having a library, which shall make application therefor, and one copy to such other institutions, societies or persons as may be designated by the Academy through its editors or its council. The remaining three hundred copies shall be turned over to the Academy to be disposed of as it may determine. In order to provide for the preservation of the same it shall be the duty of the Custodian of the State House to provide and place at the disposal of the Academy one of the unoccupied rooms of the State House, to be designated as the office of the Academy of Science, wherein said copies of said reports belonging to the Academy, together with the original manuscripts, drawings, etc., thereof can be safely kept, and he shall also equip the same with the necessary shelving and furniture.

Sec. 4. An emergency is hereby declared to exist for the immediate taking effect of this act, and it shall therefore take effect and be in force from and after its passage.

APPROPRIATION FOR 1910-1911.

The appropriation for the publication of the proceedings of the Academy during the years 1910 and 1911 was increased by the legislature in the General Appropriation bill, approved March 9, 1909. That portion of the law fixing the amount of the appropriation for the Academy is herewith given in full:

For the Academy of Science: For the printing of the proceedings of the Indiana Academy of Science, twelve hundred dollars: *Provided*, That any unexpended balance in 1909 shall be available in 1910, and that any unexpended balance in 1910 shall be available in 1911.

AN ACT FOR THE PROTECTION OF BIRDS, THEIR NESTS AND EGGS.

Sec. 602. Whoever kills, traps or has in his possession any wild bird, or whoever sells or offers the same for sale, or whoever destroys the nest or eggs of any wild bird, shall be deemed guilty of a misdemeanor and upon conviction thereof shall be fined not less than ten dollars nor more than twenty-five dollars: *Provided*, That the provisions of this section shall not apply to the following named game birds: The Anatidæ, commonly called swans, geese, brant, river and sea duck; the Rallidae, commonly called rails, coots, mud-hens, gallinules; the Limicolae, commonly called shore birds, surf birds, plover, snipe, woodcock, sandpipers, tattlers and curlew; the Gallinae, commonly called wild turkeys, grouse, prairie chickens, quails and pheasants; nor to English or European house sparrows, crows, hawks or other birds of prey. Nor shall this section apply to persons taking birds, their nests or eggs, for scientific purposes, under permit, as provided in the next section.

Sec. 603. Permits may be granted by the Commissioner of Fisheries and Game to any properly accredited person, permitting the holder thereof to collect birds, their nests or eggs for strictly scientific purposes. In order to obtain such permit the applicant for the same must present to such Commissioner written testimonials from two well-known scientific men certifying to the good character and fitness of such applicant to be entrusted with such privilege, and pay to such Commissioner one dollar therefor and file with him a properly executed bond in the sum of two hundred dollars, payable to the State of Indiana, conditioned that he will obey the terms of such permit, and signed by at least two responsible citizens of the State as sureties. The bond may be forfeited, and the permit revoked upon proof to the satisfaction of such Commissioner that the holder of such permit has killed any bird or taken the nest or eggs of any bird for any other purpose than that named in this section.

Indiana Academy of Science.

OFFICERS, 1910-1911.

PRESIDENT

Charles R. Dryer.

VICE-PRESIDENT

D. W. Dennis

SECRETARY

A. J. Bigney.

ASSISTANT SECRETARY

E. A. Williamson.

PRESS SECRETARY

Milo H. Stuart.

TREASURER

W. J. Moenkhaus

EXECUTIVE COMMITTEE

C. R. Dryer,
A. J. Bigney,
E. A. Williamson,
Milo H. Stuart,
W. J. Moenkhaus,
P. N. Evans,
A. L. Foley,
Glenn Culbertson,
D. M. Mottier,
Robert Hessler,
John S. Wright,
Carl L. Mees,
W. S. Blatchley,
H. W. Wiley,
M. B. Thomas,
D. W. Dennis,
C. H. Eigenmann,
C. A. Waldo,
Stanley Coulter,
A. W. Butler
W. A. Noyes,
J. C. Arthur,
O. P. Hay,
T. C. Mendenhall,
J. C. Branner,
J. P. D. John,
J. M. Coulter,
D. S. Jordan.

CURATORS

Botany.......................................J. C. Arthur.
Ichthyology.......................................C. H. Eigenmann.
Herpetology, Mammalogy, Ornithology.......................................A. W. Butler.
Entomology.......................................W. S. Blatchley.

COMMITTEES, 1910-1911.

PROGRAM.

W. A. Cogshall, R. S. Hessler, D. Bodine.

MEMBERSHIP.

M. B. Thomas, R. R. Ramsey, W. W. Blanchard.

NOMINATIONS.

A. W. Butler Stanley Coulter, G. Culbertson.

AUDITING.

L. J. Rettger, F. B. Wade, F. J. Breeze.

STATE LIBRARY.

G. W. Benton, W. S. Blatchley, A. W. Butler.

RESTRICTION OF WEEDS AND DISEASES.

R. Hessler, J. N. Hurty, A. W. Butler, S. Coulter, D. M. Mottier.

DIRECTORS OF BIOLOGICAL SURVEY.

Stanley Coulter, J. C. Arthur, M. B. Thomas, C. H. Eigenmann, U. O. Cox.

RELATIONS OF THE ACADEMY TO THE STATE.

M. B. Thomas, R. W. McBride, G. Culbertson, C. C. Deam.

DISTRIBUTION OF THE PROCEEDINGS.

J. S. Wright, H. L. Bruner, G. W. Benton, A. J. Bigney.

PUBLICATION OF PROCEEDINGS.

L. J. Rettger, Editor, D. Bodine, D. M. Mottier.

OFFICERS OF THE INDIANA ACADEMY OF SCIENCE.

Years.	President.	Secretary.	Asst. Secretary.	Press Secretary.	Treasurer.
1885-1886	David S. Jordan	Amos W. Butler			O. P. Jenkins.
1886-1887	John M. Coulter	Amos W. Butler			O. P. Jenkins.
1887-1888	J. P. D. John	Amos W. Butler			O. P. Jenkins.
1888-1889	John C. Branner	Amos W. Butler			O. P. Jenkins.
1889-1890	T. C. Mendenhall	Amos W. Butler			O. P. Jenkins.
1890-1891	O. P. Hay	Amos W. Butler			O. P. Jenkins.
1891-1892	J. L. Campbell	Amos W. Butler			C. A. Waldo.
1892-1893	J. C. Arthur	Amos W. Butler	Stanley Coulter W. W. Norman		C. A. Waldo.
1893-1894	W. A. Noyes	C. A. Waldo	W. W. Norman		W. P. Shannon.
1894-1895	A. W. Butler	John S. Wright	A. J. Bigney		W. P. Shannon.
1895-1896	Stanley Coulter	John S. Wright	A. J. Bigney		W. P. Shannon.
1896-1897	Thomas Gray	John S. Wright	A. J. Bigney		W. P. Shannon.
1897-1898	C. A. Waldo	John S. Wright	A. J. Bigney	Geo. W. Benton	J. T. Scovell.
1898-1899	C. H. Eigenmann	John S. Wright	E. A. Schultze	Geo. W. Benton	J. T. Scovell.
1899-1900	D. W. Dennis	Johd S. Wright	E. A. Schultze	Geo. W. Benton	J. T. Scovell.
1900-1901	M. B. Thomas	John S. Wright	E. A. Schultze	Geo. W. Benton	J. T. Scovell.
1901-1902	Harvey W. Wiley	John S. Wright	Donaldson Bodine	Geo. W. Benton	J. T. Scovell.
1902-1903	W. S. Blatchley	John S. Wright	Donaldson Bodine	G. A. Abbott	W. A. McBeth.
1903-1904	C. L. Mees	John S. Wright	J. H. Ransom	G. A. Abbott	W. A. McBeth.
1904-1905	John S. Wright	Lynn B. McMullen	J. H. Ransom	G. A. Abbott	W. A. McBeth.
1905-1906	Robert Hessler	Lynn B. McMullen	J. H. Ransom	Charles R. Clark	W. A. McBeth.
1906-1907	D. M. Mottier	Lynn B. McMullen	J. H. Ransom	G. A. Abbott	W. A. McBeth.
1907-1908	Glenn Culbertson	J. H. Ransom	A. J. Bigney	G. A. Abbott	W. A. McBeth.
1908-1909	A. L. Foley	J. H. Ransom	A. J. Bigney	G. A. Abbott	W. A. McBeth.
1909-1910	P. N. Evans	Geo. W. Benton	A. J. Bigney	John W. Woodhams	W. J. Moenkhaus.
1910-1911	C. R. Dryer	A. J. Bigney	E. A. Williamson	Milo H. Stuart	W. J. Moenkhaus.

CONSTITUTION.

ARTICLE I.

Section 1. This association shall be called the Indiana Academy of Science.

Sec. 2. The objects of this Academy shall be scientific research and the diffusion of knowledge concerning the various departments of science, to promote intercourse between men engaged in scientific work, especially in Indiana; to assist by investigation and discussion in developing and making known the material, educational and other resources and riches of the State; to arrange and prepare for publication such reports of investigation and discussions as may further the aims and objects of the Academy as set forth in these articles.

Whereas, The State has undertaken the publication of such proceedings, the Academy will, upon request of the Governor, or of one of the several departments of the State, through the Governor, act through its council as an advisory body in the direction and execution of any investigation within its province as stated. The necessary expenses incurred in the prosecution of such investigation are to be borne by the State; no pecuniary gain is to come to the Academy for its advice or direction of such investigation.

The regular proceedings of the Academy as published by the State shall become a public document.

ARTICLE II.

Section 1. Members of this Academy shall be honorary fellows, fellows, non-resident members or active members.

Sec. 2. Any person engaged in any department of scientific work, or in original research in any department of science, shall be eligible to active membership. Active members may be annual or life members. Annual members may be elected at any meeting of the Academy; they shall sign the constitution, pay an admission fee of two dollars and thereafter an annual fee of one dollar. Any person who shall at one time contribute fifty dollars to the funds of this Academy may be elected a life member of the Academy, free of assessment. Non-resident members may be elected from those who have been active members but who have removed from the State. In any case, a three-fourths vote of the members present shall elect to membership. Applications for membership in any of the foregoing classes shall be referred to a committee on application for membership, who shall consider such application and report to the Academy before the election.

Sec. 3. The members who are actively engaged in scientific work, who have recognized standing as scientific men, and who have been members of the Academy at least one year, may be recommended for nomination for election as fellows by three fellows or members personally acquainted with their work and character. Of members so nominated a number not exceeding five in one year may, on recommendation of the Executive Committee, be elected as fellows. At the meeting at which this is adopted, the members of the Executive Committee for 1894 and fifteen others shall be elected fellows, and those now honorary members shall become honorary fellows. Honorary fellows may be elected on account of special prominence in science, on the written recommendation of two members of the Academy. In any case a three-fourths vote of the members present shall elect.

ARTICLE III.

Section 1. The officers of this Academy shall be chosen by ballot at the annual meeting, and shall hold office one year. They shall consist of a President, Vice-President, Secretary, Assistant Secretary, Press Secretary and Treasurer, who shall perform the duties usually pertaining to their respective offices and in addition, with the ex-presidents of the Academy, shall constitute an Executive Committee. The President shall, at each annual meeting, appoint two members to be a committee, which shall prepare the programs and have charge of the arrangements for all meetings for one year.

Sec. 2. The annual meeting of this Academy shall be held in the city of Indianapolis within the week following Christmas of each year, unless otherwise ordered by the Executive Committee. There shall also be a summer meeting at such time and place as may be decided upon by the Executive Committee. Other meetings may be called at the discretion of the Executive Committee. The past Presidents, together with the officers and

Executive Committee, shall constitute the council of the Academy, and represent it in the transaction of any necessary business not especially provided for in this constitution, in the interim between general meetings.

Sec. 3. This constitution may be altered or amended at any annual meeting by a three-fourths majority of the attending members of at least one year's standing. No question of amendment shall be decided on the day of its presentation.

BY-LAWS.

1. On motion, any special department of science shall be assigned to a curator, whose duty it shall be, with the assistance of the other members interested in the same department, to endeavor to advance knowledge in that particular department. Each curator shall report at such time and place as the Academy shall direct. These reports shall include a brief summary of the progress of the department during the year preceding the presentation of the report.

2. The President shall deliver a public address on the morning of one of the days of the meeting at the expiration of his term of office.

3. The Press Secretary shall attend to the securing of proper newspaper reports of the meetings and assist the Secretary.

4. No special meeting of the Academy shall be held without a notice of the same having been sent to the address of each member at least fifteen days before such meeting.

5. No bill against the Academy shall be paid without an order signed by the President and countersigned by the Secretary.

6. Members who shall allow their dues to remain unpaid for two years, having been annually notified of their arrearage by the Treasurer, shall have their names stricken from the roll.

7. Ten members shall constitute a quorum for the transaction of business.

MEMBERS.

FELLOWS.

† . A. Abbott	*1908	Fargo, N. D.
R. J. Aley	1898	Orono, Me.
J. C. Arthur	1894	Lafayette.
H. E. Barnard	1910	Indianapolis.
J. W. Beede	1906	Bloomington.
George W. Benton	1896	Indianapolis.
A. J. Bigney	1897	Moores Hill.
Katherine Golden Bitting	1895	Lafayette.
W. S. Blatchley	1893	Indianapolis.
Donaldson Bodine	1899	Crawfordsville.
F. J. Breeze	1910	Lafayette.
H. L. Bruner	1899	Indianapolis.
Severance Burrage	1898	Lafayette.
A. W. Butler	1893	Indianapolis.
W. A. Cogshall	1906	Bloomington.
†Mel. T. Cook	1902	Newark, Del.
†John M. Coulter	1893	Chicago, Ill.
Stanley Coulter	1893	Lafayette.
U. O. Cox	1908	Terre Haute.
Glenn Culbertson	1899	Hanover.
E. R. Cumings	1906	Bloomington.
S. C. Davisson	1908	Bloomington.
C. C. Deam	1910	Indianapolis.
D. W. Dennis	1895	Richmond.
C. R. Dryer	1897	Terre Haute.
C. H. Eigenmann	1893	Bloomington.
Percy Norton Evans	1901	West Lafayette.
A. L. Foley	1897	Bloomington.
M. J. Golden	1899	Lafayette.
†W. F. M. Goss	1893	Urbana, Ill.
Thomas Gray (Died Dec. 19, 1908)	1893	Terre Haute.

*Date of election.
†Non-resident.

A. S. Hathaway	*1895	Terre Haute.
W. K. Hatt	1902	Lafayette.
Robert Hessler	1899	Logansport.
J. N. Hurty	1910	Indianapolis.
†H. A. Huston	1893	Baltimore, Md.
Edwin S. Johonnott	1904	Terre Haute.
Robert E. Lyons	1896	Bloomington.
W. A. McBeth	1904	Terre Haute.
†V. F. Marsters	1893	Santiago, Chili.
C. L. Mees	1894	Terre Haute.
†J. A. Miller	1904	Swarthmore.
W. J. Moenkhaus	1901	Bloomington.
Richard B. Moore	1910	Indianapolis.
D. M. Mottier	1893	Bloomington.
J. P. Naylor	1903	Greencastle.
†W. A. Noyes	1893	Urbana, Ill.
Rolla R. Ramsey	1906	Bloomington.
J. H. Ransom	1902	Lafayette.
L. J. Rettger	1896	Terre Haute.
David Rothrock	1906	Bloomington.
J. T. Scovell	1894	Terre Haute.
Albert Smith	1908	Lafayette.
†Alex Smith	1893	Chicago, Ill.
W. E. Stone	1893	Lafayette.
†Joseph Swain	1898	Swarthmore, Pa.
M. B. Thomas	1893	Crawfordsville.
†C. A. Waldo	1893	St. Louis, Mo.
†F. M. Webster	1894	Washington, D. C.
Jacob Westlund	1904	Lafayette.
†H. W. Wiley	1895	Washington, D. C.
W. W. Woollen	1908	Indianapolis.
John S. Wright	1894	Indianapolis.

*Date of election.
†Non-resident.

NON-RESIDENT MEMBERS.

George H. Ashley	Washington, D. C.
J. C. Branner	Stanford, University, Cal.

M. A. Brannon.................................Grand Forks, N. D.
D. H. Campbell.................................Stanford University, Cal.
H. W. Clark.................................Washington, D. C.
H. B. Dorner.................................Urbana, Ill.
A. Wilmer Duff.................................Worcester, Mass.
B. W. Everman.................................Washington, D. C.
W. A. Fiske.................................Los Angeles, Cal.
C. W. Garrett.................................Pittsburg, Pa.
Charles H. Gilbert.................................Stanford University, Cal.
C. W. Greene.................................Columbia, Mo.
C. W. Hargit.................................Syracuse, N. Y.
O. P. Hay.................................Washington, D. C.
Edward Hughes.................................Stockton, Cal.
O. P. Jenkins.................................Stanford University, Cal.
C. T. Knipp.................................Urbana, Ill.
D. S. Jordan.................................Stanford University, Cal.
J. S. Kingsley.................................Tufts College, Mass.
D. T. McDougal.................................Tucson, Arizona.
L. B. McMullen.................................Valley City, N. D.
T. C. Mendenhall.................................Worcester, Mass.
J. F. Newsom.................................Stanford, University, Cal.
A. H. Purdue.................................Fayettesville, Ark.
A. B. Reagan.................................Orr, Minn.
J. R. Slonaker.................................Stanford University, Cal.
Alfred Springer.................................Cincinnati, Ohio.
Robert B. Warder (Deceased).................................Washington, D. C.
Ernest Walker.................................Fayettesville, Ark.
G. W. Wilson.................................Fayette, Ia.

ACTIVE MEMBERS.

C. E. Agnew.................................Delphi.
L. E. Allison.................................West Lafayette.
H. W. Anderson.................................Ladoga.
Paul Anderson.................................Crawfordsville.
H. F. Bain.................................San Francisco, Cal.
Walter D. Baker.................................Indianapolis.
Walter M. Baker.................................Redkey.

Edward Hugh Bangs	Indianapolis.
Howard J. Banker	Greencastle.
H. H. Barcus	Indianapolis.
W. H. Bates	West Lafayette.
Guido Bell	Indianapolis.
Ray Bellamy	Moores Hill.
Lee F. Bennett	Valparaiso.
Thomas Billings	West Lafayette.
Harry Eldridge Bishop	Indianapolis.
Lester Black	Bloomington.
William N. Blanchard	Greencastle.
Charles S. Bond	Richmond.
A. A. Bourke	Edinburg.
Omer C. Boyer	Lebanon.
H. C. Brandon	Daleville.
Chas. Brossmann	Indianapolis.
E. M. Bruce	Terre Haute.
Wm. R. Butler	Indianapolis.
Edward N. Canis	Indianapolis.
E. Kate Carman	Indianapolis.
Lewis Clinton Carson	Detroit, Mich.
Herman S. Chamberlain (Deceased)	Indianapolis.
E. J. Chansler	Bicknell.
A. G. W. Childs	Kokomo.
C. D. Christie	Cincinnati, O.
J. H. Clark	Connersville.
Otto O. Clayton	Portland.
H. M. Clem	Chicago, Ill.
Charles Clickner	Silverwood, R. D. No. 1.
Charles A. Coffey	Petersburg.
William Clifford Cox	Columbus.
J. A. Cragwall	Crawfordsville.
M. E. Crowell	Franklin.
Chas. M. Cunningham	Indianapolis.
Lorenzo E. Daniels	Laporte.
E. H. Davis	West Lafayette.
Melvin K. Davis	Terre Haute.
Charles C. Deam	Indianapolis.

E. M. Deem	Frankfort.
Harry F. Dietz	Indianapolis.
James P. Dimonds	Indianapolis.
Martha Doan	Westfield.
J. P. Dolan	Syracuse.
David A. Drew	Bloomington.
Hans Duden	Indianapolis.
Arthur E. Dunn	Logansport.
Herbert A. Dunn	Logansport.
M. L. (Durbin) Ellis, Mrs	Bloomington.
J. B. Dutcher	Bloomington.
Samuel E. Earp	Indianapolis.
A. A. Eberly	Nowata, Okla.
C. R. Eckler	Indianapolis.
Max Mapes Ellis	Bloomington.
H. E. Enders	West Lafayette.
Samuel G. Evans	Evansville.
William P. Felver	Logansport.
C. J. Fink	Crawfordsville.
M. L. Fisher	West Lafayette.
Mary A. Fitch	Lafayette.
A. S. Fraley	Linden.
George M. Frier	West Lafayette.
F. D. Fuller	West Lafayette.
Austin Funk	Jeffersonville.
John D. Gabel	North Madison.
Jesse J. Galloway	Bloomington.
Andrew W. Gamble	Logansport.
H. O. Garman	Indianapolis.
J. B. Garner	Crawfordsville.
Florence A. Gates	Toledo, O.
Robert G. Gillum	Terre Haute.
E. R. Glenn	Brookville.
Frederic W. Gottlieb	Morristown.
Vernon Gould	Rochester.
Frank Cook Greene	New Albany.
Earl Grimes	Russellville.
Walter L. Hahn (Died May 31, 1911)	Springfield, S. D.

C. F. Harding.................................West Lafayette.
Mary T. Harman...............................Bloomington.
Walter W. Hart...............................Indianapolis.
Victor Hendricks.............................St. Louis, Mo.
L. R. Hessler................................Crawfordsville.
John P. Hetherington.........................Logansport.
C. E. Hiatt..................................Philadelphia, Pa.
John E. Higdon............................... ndianapolis.
Frank R. Higgins.............................Terre Haute.
S. Bella Hilands.............................Madison.
John J. Hildebrandt..........................Logansport.
Geo. N. Hoffer...............................Lafayette.
G. E. Hoffman................................Logansport.
Allen D. Hole................................Richmond.
Lucius M. Hubbard............................South Bend.
Martha Hunt..................................Indianapolis.
O. F. Hunziker...............................West Lafayette.
Roscoe R. Hyde...............................Terre Haute.
Harry M. Ibison..............................Marion.
J. Isenberger................................Louisville, Ky.
C. F. Jackson................................Durham, N. H.
D. E. Jackson................................St. Louis, Mo.
A. G. Johnson................................Lafayette.
H. E. Johnson................................Greenfield.
A. T. Jones..................................West Lafayette.
W. J. Jones, Jr..............................West Lafayette.
O. L. Kelso..................................Terre Haute.
A. M. Kenyon.................................West Lafayette.
Frank D. Kern................................Lafayette.
L. V. Ludy...................................West Lafayette.
R. W. McBride................................Indianapolis.
Richard C. McCloskey.........................Chicago, Ill.
T. S. McCulloch..............................Crawfordsville.
N. E. McIndoo................................
Edward G. Mahin..............................West Lafayette.
James E. Manchester..........................Minneapolis, Minn.
Wilfred H. Manwaring.........................New York City.
M. S. Markle.................................Richmond

William Edgar Mason	Borden.
Clark Mick	Indianapolis.
A. R. Middleton	West Lafayette.
G. Rudolph Miller	Indianapolis.
F. A. Miller	Indianapolis.
Chas. R. Moore	West Lafayette.
Geo. T. Moore	St. Louis, Mo.
Richard Bishop Moore	Indianapolis.
Herbert Morrison	Indianapolis.
Frank K. Mowrer	Marion.
F. W. Muncie	Crawfordsville.
Fred Mutchler	Bowling Green, Ky.
Leslie C. Nanney	Bedford.
Charles E. Newlin	Indianapolis.
J. A. Nieuwland	Notre Dame.
Clayton R. Orton	West Lafayette.
G. A. Osner	Crawfordsville.
D. A. Owen	Franklin.
Everett W. Owen	Indianapolis.
Ferman L. Pickett	Bloomington.
Rollo J. Pierce	Richmond.
Ralph B. Polk	Greenwood.
James A. Price	Ft. Wayne.
W. H. Rankin	Ithaca, N. Y.
C. A. Reddick	Crawfordsville.
C. J. Reilly	Syracuse.
Allen J. Reynolds	
George L. Roberts	Lafayette.
J. Schramm	St. Louis, Mo.
E. A. Schultze	Laurel.
Will Scott	Bloomington.
Charles Wm. Shannon	Brazil.
Fred Sillery	Indianapolis.
Oscar W. Silvey	West Lafayette.
Charles M. Smith	Lafayette.
C. Piper Smith	Logan, Utah.
Essie Alma Smith Shannon	Bloomington.
E. R. Smith	Indianapolis.

Geo. Spitzer.................................Lafayette.
Brenton L. Steele............................Pullman, Wash.
Chas. Stoltz.................................South Bend.
J. M. Stoddard...............................
Milo H. Stuart...............................Indianapolis.
Julius W. Sturmer............................Lafayette.
J. C. Taylor.................................Logansport.
Albert W. Thompson...........................Owensville.
A. D. Thorburn...............................Indianapolis.
Iro C. Trueblood (Miss)......................Greencastle.
William M. Tucker............................Osgood.
W. P. Turner.................................West Lafayette.
Chas. A. Vallance............................Indianapolis.
J. M. Van Hook...............................Bloomington.
W. B. Van Gorder.............................Lyons.
H. S. Voorhees...............................Ft. Wayne.
Frank B. Wade................................Indianapolis.
Luther C. Weeks..............................West Lafayette.
Mason L. Weems...............................Valparaiso.
Daniel T. Weir...............................Indianapolis.
James E. Weyant..............................Indianapolis.
Virges Wheeler...............................Montmorenci.
A. E. White..................................Connersville.
Alfred T. Wiancko............................Lafayette.
Kenneth P. Williams..........................Bloomington.
William L. Woodburn..........................Evanston, Ill.
John W. Woodhams.............................Indianapolis.
Herbert Milton Woollen.......................Indianapolis.
J. F. Woolsey................................Cleveland, O.
G. A. Young..................................West Lafayette.
Jacob P. Young...............................Huntington.
L. E. Young..................................West Lafayette.
W. J. Young..................................Washington, D. C.
Lucy Youse...................................Terre Haute.
W. A. Zehring................................West Lafayette.
Charles Zeleny...............................Urbana, Ill.

Fellows, resident	51
Non-resident	12
Members, active	197
Members, non-resident	30
Total	290

MINUTES OF THE TWENTY-SIXTH ANNUAL MEETING

INDIANA ACADEMY OF SCIENCE

CLAYPOOL HOTEL, INDIANAPOLIS, INDIANA.

NOVEMBER 24, 25, 1910.

The Indiana Academy of Science met at the Claypool Hotel, November 24-25, 1910.

The Executive Committee held its regular meeting at 8:00 p. m., November 24. The following members were present: P. N. Evans, President; C. R. Dryer, A. J. Bigney, J. S. Wright, A. W. Butler, W. S. Blatchley, George W. Benton, Robert Hessler, and W. J. Moenkhaus.

On proposal of the treasurer, W. J. Moenkhaus, the following resolution was adopted:

> Resolved, That all accounts of the members of the Academy be regarded as paid up to and including the year for which their most recent receipt has been issued.

The State Library Committee, of which A. W. Butler was chairman, reported that the State Librarian was taking special interest in the publications coming to the Academy.

The general interests of the Academy were then discussed at some length.

The regular session of the Academy was held at 9:00 a. m. Friday, November 25, Professor P. N. Evans presiding.

The Program Committee reported their work completed as given in the printed program.

The Committee on Distribution of the Proceedings reported that their work had been performed under the direction of the State Librarian, Dr. Demarchus C. Brown.

The editor, H. L. Bruner, made the following report through the Secretary:

Work performed—

Cost of regular edition	$1.070 27
Free reprints	183 55
Total	$1,253 82

The Treasurer reported as follows:

Balance from 1909	$401 22
Receipts from dues, 1910	194 00
Total	$595 22
Expenditures during 1909 as per vouchers	271 58
Balance, cash on hand November 25, 1910	$323 64

W. J. MOENKHAUS, Treasurer.

Audited and approved.

L. J. RETTGER,
F. J. BREEZE,
Auditing Committee.

The President then appointed the standing committees.

After the completion of this business, Professor P. N. Evans, as President of the Academy, read his address on "The Place of Research in the Undergraduate Schools." Dr. Demarchus C. Brown was called upon to speak concerning the books that come to the Academy through his office. He called attention to three points:

1. That two consignments of books had been bound, one of 118 volumes and one of 119 volumes.
2. That he now had 300 volumes ready for the bindery.
3. That the list of domestic exchanges was very incomplete, and that there were now 114 foreign exchanges on the list. This list was also incomplete.

He asked that a special committee in Indianapolis be appointed to quickly decide all questions relative to the publications. This work was referred to the Committee on State Library.

The reading of the regular papers in general session was then taken up.

After Dr. Hessler's paper on "Plants and Man," he presented the following resolution, which was adopted:

Resolved, That the Indiana Academy of Science hereby endorses the establishment of a National Department of Public Health, such as is advocated by the Owens bill.

Papers were read until noon.

At 2:00 p. m. the Academy went into business session. M. B. Thomas, as chairman of the Membership Committee, reported the following persons for membership:

Kenneth P. Williams.
William M. Tucker.
Jesse J. Galloway.
Herbert Morrison.
Ray Bellamy.
Charles M. Smith.
George M. Frier.
F. D. Fuller.
Mary A. Fitch.
Clayton R. Orton.
H. H. Barcus.
M. S. Markle.
J. A. Price.
Harry M. Ibison.
David A. Drew.

They were elected.

The following persons were elected fellows:

F. J. Breeze.
C. C. Deam.
J. N. Hurty.
N. E. Barnard.
R. B. Moore.

The Auditing Committee reported the books of the Treasurer correct.

The Academy was then divided into the following sections for completing the reading of the papers:

A. Zoölogy, Geology and Geography.
B. Botany.
C. Mathematics, Physics, Chemistry.

At 8:00 p. m. the Committee on Nomination of Officers, A. W. Butler chairman, reported as follows:

President—Charles R. Dryer.

Vice-President—David W. Dennis.

Secretary—Andrew J. Bigney.

Assistant Secretary—E. A. Williamson.

Press Secretary—Milo H. Stuart.

Treasurer—W. J. Moenkhaus.

They were elected as read.

On motion of Stanley Coulter, it was decided that it is the sense of this Academy that hereafter the nomination for vice-presidents shall not carry with it the promotion to the office of president.

President P. N. Evans then asked Professor Stanley Coulter to introduce the speaker of the evening, Dr. D. T. MacDougal, of the Desert Laboratory, Tucson, Arizona.

Dr. MacDougal's subject was "Desert Days and Desert Ways." It was fully illustrated with numerous lantern slides. This lecture was one of great worth to every person present, and it was greatly enjoyed and appreciated.

SPRING MEETING.

NASHVILLE, BROWN COUNTY, MAY 20-21, 1910.

The spring meeting of the Academy was held in Brown County on the above date. The program, as planned, was carried out successfully and members who were able to attend reported a pleasant time. The Indianapolis Southern Railroad gave us a special car from Indianapolis at 7:20 Friday morning, May 20th. We arrived at Helmsburg at 8:35, where we were joined by members of the Academy who came from Bloomington. The party was met by Joshua Bond, liveryman, with two hacks, and without delay, some riding and some walking, set out for Waltman's and Freeman's orchards and the Bear Wallow. A lunch of ham sandwiches and buttermilk was served here, and after a rest the route was followed down the ridge into the valley and along the road which follows Grease Creek, into Nashville, where we arrived at 2:45, tired but happy. We left Helmsburg in mud and mist, but the day gradually brightened until by the time we left Bear Wallow the sun was shining brightly.

The rest of the afternoon was spent in viewing historic and interesting sights in and about Nashville. Dinner at 5:30 at Pittman's Inn was followed by two hours of social chat upon the broad piazzas of this sanatorium. At 7:45 three additional members arrived, including Mr. Blatchley, who was unable to be present during the day and who was booked for the principal address of the evening.

The public meeting was held in the court house at Nashville. In the absence of President P. N. Evans and of Vice-President C. R. Dryer, past President D. W. Dennis, of Earlham, was asked to preside. Professor Dennis spoke of the work of the members of the Academy for the State and of the interest which the people should take in the Academy. He introduced Dr. Eigenmann, who spoke briefly on his South American fishing experiences. Following Dr. Eigenmann, Mr. Blatchley was introduced and gave his lecture on the "Indiana of Nature," illustrated by many charts showing the geological growth of the State. This address was enjoyed by the audience, which comfortably filled the court room.

Saturday morning the party separated into groups. Some of them returned on the early trains, others returned at noon, and still others stayed until the following day, visiting Weed Patch hill and other points of interest. The day started out rather threatening, but it gradually cleared. Altogether, considering the time of year, the weather was quite favorable and the roads unusually good. The following members of the Academy were present:

W. S. Blatchley,	G. M. Frier,
Donaldson Bodine,	W. C. Goble,
G. W. Benton,	Roscoe R. Hyde,
E. R. Cumings,	William A. McBeth,
G. W. Childs,	Robert W. McBride,
Charles C. Deam,	R. R. Ramsey,
David W. Dennis,	Charles Stoltz,
C. H. Eigenmann,	J. M. Van Hook,
Arthur L. Foley,	W. F. VanGorder,
E. S. Ferry,	J. S. Wright.

George W. Benton, Secretary.

PROGRAM OF THE TWENTY-SIXTH ANNUAL MEETING

INDIANA ACADEMY OF SCIENCE

CLAYPOOL HOTEL, INDIANAPOLIS, INDIANA,

November 25, 1910.

P. N. EVANS, President. — CHARLES R. DRYER, Vice-President.
GEORGE W. BENTON, Secretary. — A. J. BIGNEY, Assistant Secretary.
W. J. MOENKHAUS, Treasurer. — H. L. BRUNER, Editor.

PROGRAM.

FRIDAY, NOVEMBER 25.

9:00 A. M., General Meeting.

Business.

President's Address.

Plants and Man—Weeds and Disease, 20 minutes..........Robert Hessler

An Outline Review of Indiana Municipal Water Supplies. 5 minutes ....Charles Brossman

A New Building for the Department of Practical Mechanics at Purdue University, 10 minutes....................M. J. Golden

Features of Subterranean Drainage in the Bloomington Quadrangle, 30 minutes.................................J. W. Beede

The Shi-Shi Cig, 3 minutes...........................Albert B. Reagan

Notes on the Shaker Church of the Indians, 5 minutes....Albert B. Reagan

The Wreck of the "Suthern," 5 minutes..................Albert B. Reagan

The Bois Fort Indian Reservation in Minnesota, 8 minutes Albert B. Reagan

Conservation Problems in Indiana, 12 minutes.........Frederick J. Breeze

2:00 P. M., Sectional Meetings.

ZOÖLOGY, GEOLOGY AND GEOGRAPHY.

Geology of Croy's Creek, Clay Co., Ind., 10 minutes.........C. W. Shannon

The Properties and Reactions of Thrombin, 10 minutes......L. J. Rettger

Some Conglomerate Beds of Post Glacial Origin, 5 minutes .... Glenn Culbertson
The Nature and Origin of the Fish Fauna of the Plateau of British Guiana, 15 minutes .... C. H. Eigenmann
A Physiographic Survey of the Terre Haute Area—Reports of Progress, 10 minutes .... Charles R. Dryer
The Work Done by Normal Brook in Thirteen Years, 20 minutes .... Charles R. Dryer and Melvin K. Davis
Paleolithic, Neolithic, Copper and Iron Ages of Shelby Co., Ind., 10 minutes .... F. W. Gottlieb
The Effects of Ice in Lakes Upon the Shore Lines of the Same, 3 minutes .... Albert B. Reagan
A New Bed of Trilobites, 5 minutes .... A. J. Bigney
The Fauna of the Brazil Limestone .... F. C. Greene

MATHEMATICS, PHYSICS AND CHEMISTRY.

The Preparation of Ether, 5 minutes .... P. N. Evans
The Temperature Coefficient of the Surface Tension of Water, 15 minutes .... Arthur L. Foley
LaPlace's Theory of Capillarity, 10 minutes .... Arthur L. Foley
A Derivation of Poisson's Equation, 10 minutes .... Kenneth P. Williams
The Value at Low Temperatures of the Specific Heats of a Gas .... C. M. Smith
Gaseous Fermentation in Sweetened Condensed Milk, 40 minutes .... O. F. Hunziker
Investigations Concerning the Reichert-Meissl No. and the Relations of Butter Fat Constants in Butter Analysis .... George Spitzer
A Convenient Laboratory Device, 5 minutes .... J. P. Naylor

BOTANY.

Some Anomalies in the Gametophyte of Dryopteris stipularis, 5 minutes .... Caroline A. Black
The Flora of Eastern Nova Scotia, 10 minutes .... Stanley Coulter
The Weed Problem in Indiana, 10 minutes .... Stanley Coulter
The Heteroecious Rusts with Aecia on Euphorbia .... Mary A. Fitch
An Example of Persistent Life, 2 minutes .... D. A. Owen
Indiana Fungi, 5 minutes .... J. M. Van Hook
Steccherinum septentrionale (Fr.) Banker in Indiana, 10 minutes .... Howard J. Banker

The Water Balance of Desert Plants, 15 minutes.........D. F. MacDougal
Disease Resistance in Varieties of Potatoes..................C. R. Orton
The Laboratory Method of Determining the Fungicidal
Value of Spraying Mixtures, 10 minutes.................L. R. Hessler
The Black Knot of Plum, 10 minutes..........................H. L. Rees
Additions to the Indiana Flora, 3 minutes................Charles C. Deam
An Ecological Survey of the Lower Whitewater Gorge, 15
minutes ....M. S. Markle and L. C. Petry
Report of Work on Corn Pollination II, 3 minutes............M. L. Fisher

8:00 p. m., Address, illustrated by stereopticon, by Dr. D. T. MacDougal, of the Desert Laboratory, Tucson, Arizona.

President's Address.

By Percy Norton Evans.

THE PLACE OF RESEARCH IN UNDERGRADUATE SCHOOLS.

The aim of this Academy is the encouragement of research along scientific lines by establishing and maintaining intercourse among those engaged therein, thus stimulating them by a consciousness of companionship in productive intellectual activity. In a small society, embracing in its scope all the sciences, one does not expect in these days of specialization to find others engaged in just the same field of investigation as himself; it is through inspiration rather than information that the investigator profits by these meetings.

It is now hardly necessary to emphasize, even to the non-scientific public, the importance of scientific research; to it mankind owes in a large measure not only his material prosperity, comforts, and conveniences, which is sufficiently obvious, but, what is even more important, his intellectual freedom. The changes that have taken place within the last century in our physical environment, with the innumerable applications of science to useful purposes, are no more profound than our intellectual advance and the growing pervasiveness of the scientific spirit in all lines of thought, and in the endeavor for human betterment, physcial, social and moral. Our increasingly extensive and effective philanthropies, our giant strides in sanitary administration, and the tottering barriers between the sects of Christendom, are very tangible evidences of the spirit that is not satisfied with precedent or authority, but craves certainty as to the facts, and reasonable explanations for them, as well as aims at the application of all knowledge to the uses of man.

The membership of this Academy happily includes scientific workers in many fields. Some apply the results of research to the needs of the State in developing its resources and protecting its citizens against the injuries inflicted by ignorance and fraud; others make science the servant of industry and commerce; others, again, are active in applying it to the preserving and restoring of the health of our bodies. A large part of our membership, however, is made up of those whose chief occupation is teaching.

While it has not always been the case, it is probably true at present that the most valuable contributions to human knowledge are made by those engaged in this profession of teaching. This is not surprising, for the nature of his calling demands that the teacher to be effective must ever continue to be a student, and the thorough study of any subject reveals the limits of our knowledge in that field and tempts the man of active intellect to the task of extending those boundaries; there is surely no keener pleasure than the learning by one's own search some truth, however inconspicuous, not previously known.

Not only does teaching tend to stimulate research, it also gives it balance by preventing the too exclusive attention to the comparatively narrow field under intensive cultivation; the necessity of presenting well-ordered information covering the broader subject, and the oral statement of original theories and conclusions, must have a broadening and clarifying influence on the intellectual activity of the investigator.

As teaching is a help to research, still more is research a vitalizer of teaching, particularly of the teaching appropriate for graduate students; indeed, the work of research is at least as important as that of instruction where advanced students are concerned, and the university should be a source of knowledge, where those desiring to devote themselves to the same high quest may be stimulated by the example and companionship of productive scholars.

The leading European nations have apparently realized more clearly than we the value of scientific research, and have provided more adequate rewards and more favorable environment for the investigator, with the result that the ratio of intellectual to material prosperity is higher there than here. Within the past generation, however, we have become more awake to these matters, and have determined in our strenuous way to make research "hum." The awakening has unquestionably been beneficial on the whole, but we have, it seems to me, failed to grasp certain fundamental distinctions between the needs of graduate and of undergraduate students; the hum of research has been allowed to drown the cries of the injured in many an undergraduate school, where teaching is sacrificed to research, and where too early specialization is encouraged and even forced upon the student.

We are not as yet in this country producing our proper share of scholars of the first rank. The reasons for this are many, including hasty preparation, premature specialization, insufficient rewards, and unfavorable environment.

As to preparation, those of us who contemplate academic careers are usually unwilling to invest sufficient capital of time and money; we expect to complete our scholastic education if uninterrupted at about twenty-five years of age and then enter upon an active career in which there is little time or opportunity for research or even very serious or intensive study, for the sake of the immediate pecuniary reward; in Europe. several more years are spent in subordinate positions as investigators, on a semi-independent basis both scholastically and financially. The European makes a larger investment and reaps a larger ultimate reward, not only in money but still more in the consideration accorded to intellectual eminence.

Concerning too early specialization and its shallow results, I shall speak later; let it suffice here to say that, for example, he is a poor chemist who is only a chemist.

The rewards at present offered for pure scientific work in this country are insufficient to attract the most vigorous, capable and ambitious men: not only, nor chiefly, are the financial returns here less than in Europe, in spite of our higher cost of living, but the public respect for intellectual distinction is far inferior in this country, on account of our commercialism and our acceptance of wealth as our standard evidence of merit.

The environment, too, is less favorable to the highest scientific work in that the numbers of those engaged therein are so few, and the national characteristic of haste rather than thoroughness pervades our activity. The value of real scientific attainment is still but dimly recognized by the industrial world; chemists are employed like clerks, without graduate training, and work like day laborers, but for less pay, at routine analysis, with neither the training nor the opportunity to attack the larger problems in a fundamental scientific way. Such chemists are not on the same plane as the higher chemists in the German manufacturing industries, who have supervision of the works as well as the laboratories. One result, then, of this lack of demand for highly trained men is the small number pursuing research in our universities, so that even our best qualified professors have a mere handful of research students, and many of these can be induced to continue their higher education only by fellowships sufficient to pay their living expenses; if such aids were discontinued the numbers of our graduate students would be even less favorably impressive than at present, though in time the larger investment of those remaining would result in the larger salaries that would have to be paid to the men more difficult to find.

The keener competition in all walks of life in Europe has some advantages—only the thoroughly trained can hope for success, hence the desire for the most complete preparation. We consider ourselves fortunate in being protected against foreign competition, and in being able in consequence to make an equally good living with less effort; but are we really to be congratulated on our lower intellectual standard of living and on our dependence upon imported thought and intellectual products?

Another result of the limited scale on which scientific investigation is being conducted, and our "high standard of living," is that it is not worth while for home manufacturers to supply refined or unusual scientific material; if an American investigator needs, for instance, a special chemical, he must wait two or three months for its importation, while his European colleague could obtain the same in as many days or even hours, or, if manufactured here, two or three times the foreign price must be paid. The American artisan is more highly paid than his European brother, but not so the more eminent intellectual worker.

Naturally the realization of the value of intellectual things is found first among those engaged in the work of education, and our larger and better endowed colleges have within the last half century shown their appreciation of productive scholarship and have developed graduate schools to compare more favorably with the European universities, so that it is no longer necessary for our students to go abroad for the inspiration of working with men who are extending the boundaries of human knowledge. Once started, the fascination of research insures its continuance as long as a favorable environment exists.

The institutions that have been able by their large means to adequately maintain graduate departments have been so amply rewarded by their enhanced prestige, that many others, without sufficient means, have attempted to do the same thing; the result has been impaired undergraduate instruction with a more or less successful imitation of graduate work.

A graduate school should recognize as its most important possession the productive scholarship of its faculty, making the institution a center of new knowledge, and all other matters should be arranged with a view to encourage and stimulate scientific investigation. A very moderate amount of class instruction and other duties should be demanded of the members of the faculty, and students should be sufficiently mature and earnest to work without compulsion and with little direction under the guidance and inspiration of the men who are doing real original work.

The case of the undergraduate school is fundamentally different. I believe that the prominence given to research in many undergraduate schools is a positive injury to the student; his instructors are chosen on account of their ability or promise as investigators instead of their qualifications as teachers, and even the student himself is encouraged or forced to undertake so-called research with entirely inadequate training, both as regards breadth and depth. The undergraduate years should be employed in acquiring a well balanced knowledge of the fundamentals of the student's specialty, and an acquaintance with the elements of many allied subjects, together with a working grasp of such tools as modern languages, to make professional literature accessible at first hand, and mathematics, for the mental training and grasp of the quantitative and statistical treatment of all studies, and every undergraduate student should give such attention to history, literature and economics as to make him an intelligent citizen and man of culture.

Only when this has been in a measure accomplished—and in looking back to our own college days we realize that a mere beginning had been made when we graduated—is the student in a position to profitably undertake research, with a proper appreciation of what he is doing and how to do it, so that it is really research for him and he is not merely a pair of hands under the direction of another's brain. The effectiveness of a scientific investigator is generally proportional to the thoroughness of his preparation; too many attempt to discover new truths before they have grasped those already discovered by others.

In many institutions one of the requirements for graduation is called a thesis, and such a tradition is difficult to dislodge, but I think the name is unfortunately pretentious and is apt to mislead the student into thinking himself more advanced than the facts justify; it savors of the same spirit that induces the high school to ape the college in so many ways, in its pernicious fraternities and even in having a "baccalaureate" service—doubtless to celebrate the fact that the boys about to graduate are still unmarried; such unwholesome symptoms are usually most conspicuous in institutions with the least merit. The preparation of an undergraduate thesis may be a valuable item in the course if it is not so administered as to waste the student's time, narrow his mind, and swell his head. I believe its most valuable feature is its compelling him to go to original sources for information, namely, library work. Too many students graduate without this experience and with a knowledge of books limited to the prescribed texts employed in the course. To choose a subject of real interest to the student and of suitably narrow scope, and to find out by systematic search in the scientific journals all that is known about it, and then to write an essay in which the information is carefully arranged and well presented, is a task well worth the performance.

It is entirely laudable for every institution to aim at ever higher goals; not, however, by raising the entrance requirements beyond the reach of its natural constituents to meet, even at the dictation of some self-appointed board demanding uniformity under diverse conditions, and not by changing the object of its training—there would not be any necessary gain to the community at large should a school of pharmacy gradually become a theological seminary or even a medical college; a school of pharmacy is just as necessary as either of the others.

It is perfectly natural for any teacher or group of teachers to aspire to more advanced grades of work, but this should not be undertaken unless the more elementary and fundamental work is adequately cared for. We are suffering from too much ambition of this kind; too many trade schools attempt to be technical colleges, and too many colleges attempt to be universities, at the expense of their efficiency in their original equally important field. Let us imagine that every grade school gradually introduced more and more work of the high school, and that every high school gradually became a college, and that every college gave more and more of its energies to graduate students! Or let us imagine that every institution giving grammar school instruction attempted also to provide training through the high school, college and university curriculum! What a ridiculous and inefficient educational system must result. Roughly speaking, for every thousand grade schools we need about a hundred high schools, ten colleges and technical schools, and one graduate university.

Fortunately there is a supervision that prevents the transformation of grade schools into high schools, and separates the work of the two as soon as numbers of pupils justify the step; it is a pity that there is no authority with power to insure similar efficiency on the part of undergraduate and graduate colleges and universities.

We are failing to appreciate the distinction between undergraduate and graduate work. In most ways there is little more in common between these than between that of the high school and of the college, and the university is injured in the attempt to make it a small part of a large college. Efforts have been made in this country to have universities unhampered by undergraduate departments; unfortunately, however, the country has declared itself not yet ready for such a logical and much to be desired arrangement.

The chief function of the undergraduate school is to give instruction in such a way as to insure mental development. For those few who are to proceed to graduate work, the soundness, breadth and depth of the foundation will largely determine the safety and usefulness of the superstructure of specialization to be erected later. The first qualification for membership in the teaching staff of an undergraduate school should be teaching ability together with a thorough knowledge of the subject to be taught.

This teaching ability is largely a natural gift, and if of a high order is not common. Let us recognize it, use it, and reward it as an asset of the highest value. It can not be created by the study of pedagogy any more than logical thinking by the study of logic; it is founded on the intuition of sympathy. Teaching is the keenest pleasure to some, the hardest drudgery to others; the student readily distinguishes the two. I would not, however, imply that even the best teacher can work effectively with the undergraduate who struggles to escape education or who is unwilling to make any effort for it because his interests are non-intellectual; such students have no proper place in an institution of higher learning, and we expend too large a part of our energy in forcing such material through to graduation. The fashionableness of going to college is by no means an unmixed blessing. Why does not some enterprising individual start a college with luxurious dormitories and means of recreation and dissipation, where work shall be optional and house parties continuous? Enormous fees could be charged, professional athletes employed, a suitable degree conferred after four years, and the working colleges protected from young men not desiring education?

Though the chief function of an undergraduate institution is instruction, and its faculty should be chosen with this in view, every such teacher, to attain his highest efficiency, should engage in some kind of research, that is, getting new information at first hand. This can not fail to have a vitalizing effect on his teaching, keeping clear the distinction between fact and theory, and maintaining his instruction abreast of the times.

There is widespread questioning of the value of much that is published as scientific research, and it is easy to criticize the spirit that piles up undigested data or adds to the number of chemical compounds for the sake of having something to publish; it is impossible to say, however, that any such information is and will continue to be valueless. I am less interested in discrediting such work because it now receives higher recognition from the undiscriminating in the educational world than it deserves, than in asking for recognition for a kind of labor, just as truly research, that now receives too scant credit from the public and from those responsible for the distribution of rewards to college teachers. I refer to what may be called pedagogical research—the labor involved in improving and constantly rejuvenating the instructional work. Any course that remains unchanged for many years is probably in need of repairs, but desirable changes usually involve much labor on the part of the instructor. The teacher whose heart is in his teaching and who carries the usual overload of duties is likely to be kept busy at just such work, and have no time left for the more conventional kinds of research; but his students will profit by his labors. The administrative officer who directly or indirectly puts pressure upon a college teacher to neglect his teaching is seriously injuring the college; yet this is by no means uncommon, intentionally or otherwise.

Research, of whatever kind, is largely a matter of inspiration, and can not be forced; as profitably might a poet be urged to become a painter as a scholar be pressed to undertake investigations foreign to his inspiration. Left to himself the investigator will do what he is most interested in and therefore likely to do most fruitfully; to attempt to force a teacher whose instincts are for pedagogical research to other kinds of investigation is likely to spoil a good teacher and make a mediocre investigator. The method of forcing commonly practiced is the indirect but very effectual one of recognition of published research by promotion and increased remuneration, while devotion to teaching and pedagogical research receive no such rewards.

Let us recall our own undergraduate experiences. Did we not in many cases get most stimulation and make most progress under teachers unknown in the professional journals? It is to be expected, indeed, that the teacher whose chief pride and interest are in his teaching, and whose chief reward is the advancement of his students, should be of more real value to those students, than the investigator whose hours of reflection are devoted to the problems of his research, and to whom the instruction of classes is incidental if not, as in many cases, an unwelcome interruption. Gifts of an equally high order for instruction and for investigation are not usually found in the same individual; let each give his main effort to what he can do best; let the investigator work with mature students and the teacher with the immature, and let the distributors of rewards make no invidious distinctions in the recognition of the two equally necessary and meritorious services.

While it is eminently desirable that a teacher should be also an investigator, in every faculty, some members have more pronounced ability than others in this direction, and it is proper that such should receive special consideration as to other demands upon their time and attention in order to enhance their productiveness by favorable conditions. To the others, whose bent is less marked in the direction of research, should be assigned the duties of administration and the committee work, with, if necessary, the high school commencement addresses. Neither should the more general business of the college be regarded as of any less value or importance than research, or less worthy of reward. To be sure it has not the same advertising value, but an institution of learning should be above adopting the motto "quick returns and small profits." The most enduring good accrues to the students, and therefore to the college, from inspired teaching and wise and careful administration.

It is the part of wisdom to provide as favorable conditions as circumstances will permit for the encouragement of research.

Several factors more or less obvious enter into this favorable environment and influence the productiveness of the investigator, but the real determining factor is in the man himself; he must have ideas, enthusiasm, and industry; he may even be a crank; he must have an accurate memory to retain the results of extensive reading, and as much as any one can profit by good health, to withstand the strain of concentrated and continuous effort; he must be absolutely honest with himself and the professional world. If he has the necessary qualities it is very unfortunate if his circumstances do not permit their most fruitful activity; if he has not, let him serve his institution in other ways for which he is better fitted—ways of equal importance. Few men can spend several hours daily with classes, several more in administrative work, one or two more in committees, and have any vitality left either for research or professional growth.

The greatest need of most successful college teachers is more time to think. The evil effects of the prevalent rush become apparent only very slowly—in the course of years—in a gradually failing effectiveness for lack of mental nourishment. No one can use a few minutes now and then, snatched from the more urgent duties of the moment, to do or even think real research; ideas do not come on demand, interruptions are often fatal to inspiration, experimental work often must be continuous to lead to results; investigation that is worth while is not a routine operation to be started and stopped by a gong; there must be mental growth as a background. It would probably be economical in the long run if the real teacher-investigator could be assured of uninterrupted privacy for half of every day.

In addition to time for thought, reading, experimentation and writing, the teacher of science needs space and material equipment. There is a temptation to spend money most freely in ways that lead to the most tangible results, and would-be benefactors may cause serious embarrassment by providing buildings without equipment or endowment; blessed be the liberal contributors to the "general fund," meaning equipment and, most important of all, competent men.

In the providing of suitable buildings with limited means, circumstances must decide how much can be devoted to what may be called luxuries and quality as against necessities and quantity; it is certainly desirable to have buildings as beautiful as possible, but not at the expense of adequate size and equipment.

Books are too often a crying need; they cost so much and they show so little; and yet without them research is impossible. The most serious lack is usually that of complete files of the scientific journals, which can *never* be purchased on a non-accumulating allowance of a hundred dollars a year. The value of the library habit to the student can hardly be overestimated, but to develop this plenty of books and an attractive place for reading them are almost indispensable. How welcome to the business manager of many a college in straitened circumstances would be the professor who "did not read books but wrote them."

Turning now to the question of assistance, from the purely business standpoint a man should not be required to do what a cheaper man can do as well; the problem, however, is by no means solved by so stating it. The profitable use of assistants is a far from simple matter; their duties should be so assigned and supervised that their time may be spent to the advantage of the department and also to their own obvious profit. The men available have usually recently graduated and should realize that the salary is not the chief reward for their services, but that the time spent as an assistant in a well conducted department is valuable as a period of education and necessarily precedes any more advanced position in the college or university world. The assistant should welcome all such experience, even if some drudgery is included, as give him an insight into the teaching of his subject and the management of departmental business, such as the handling and ordering of supplies, the administration of classes, and the keeping of systematic records. To really review and extend his knowledge of the fundamentals of his subject so as to meet the needs of students entitled to his help is no slight task, but the assistant should use his utmost efforts towards progress in more advanced study and in research if his preparation is adequate. The assistant who shows the right qualities will not long fail to receive recognition and promotion; in the teacher's profession "everything comes to him as can wait" as far as he has the qualifications. Given the natural ability, industry and personality, thorough preparation will compel success; an assistant's position in a large and efficient department in association with successful men is better preparation for ultimate success in college or university work than the better paid positions in high schools open to men of equal training.

Those having charge of assistants should see to it that there is opportunity and encouragement for proper growth. It is through such assistants that the older teachers may hope to accomplish research, in doing which both are equally benefited. It is, however, something of a deception to call such assistants' positions "fellowships" if the duties of the department occupy any considerable part of the time.

It is certainly desirable that the more experienced teacher should delegate to assistants such of his work as can be properly done by them; it is very undesirable that he should cease to have direct and constant contact with the work of students; the direction and development of courses should remain actually in his hands and the work of assistants be under constant scrutiny. When it becomes impossible for a course to continue actually under the direct management of a senior instructor it should be placed in charge of a qualified associate whose responsibility will be the incentive for his best work; the plan followed in some universities of having courses nominally in the hands of those for whom it is impossible to actually direct the work, which is really done by junior men, is essentially unfair to the latter in withholding from them the credit to which they are entitled, not conducive to the best results in that it fails to provide the incentive for devoted effort on the part of those actually planning and administering the work, and an imposition on the college and the public, who believe the courses to be really administered by the more widely known teacher. Many a student has been disappointed in finding that he has little or no contact with the man advertised as having the work in charge.

In growing institutions it is the usual experience of the teacher that other duties encroach more and more upon his instruction and research, the latter being first sacrificed. Some of these are indispensable, such as the keeping of accurate records of students' work, and as institution and department grow there is some unavoidable increase in the machinery for handling students; the red tape and machinery should be recognized as a necessary evil—a means not an end—and kept at a minimum; if the choice were imposed between good teaching with no records and good records with no teaching, the election would be simple. There may be a conflict of opinion on this subject, however, between the engineer of the beautiful machine and the poor laborer whose energies are consumed in feeding it with reports. I believe that we devote too large a part of our attention to the lazy and incompetent, to the detriment of the more energetic and able students on account of the struggle for the prestige accorded to numbers, which we may also charge with the use of colleges as lounging places for the sport and the intellectual dead-beat. It is surely unfortunate if a teacher has to spend his time in keeping elaborate records of and forcing the loafers instead of stimulating and satisfying the gifted.

The question of salary has an intimate bearing upon the efficiency of college teachers, and it is generally admitted that they are underpaid. The cost of living varies so widely in different college towns that a salary adequate in one would be entirely insufficient in another, so that it is impossible to name a suitable figure. As a general principle, however, it may be accepted that the remuneration should be enough to attract men of energy and ability and make possible their best work. It is not desirable that teachers should vie with the commercial classes in display or in expensive amusements, and men of intellectual strength would not wish to; it is proper that they should receive enough to permit comfort without anxiety, membership in scientific societies and the attendance upon their meetings, books and other professional tools, and also travel, society, and the enjoyment of music and art, for the sake of their own broad development and consequent influence in society as well as with their students. The man who never sees anything but his home and his place of business is certain to be narrow. Many young men ruin their professional prospects by marrying on a very small income even before their education is complete; it is no evidence of a lack of sentiment for a man to postpone marriage until he is in a position to properly maintain a family. Further, it is surely the cause or the result of a second rate qualification as a college teacher to attempt to carry on another business with no bearing upon his professional pursuits for the sake of the increased income. Scarcely less valuable is the semi-professional routine of tutoring, commercial analysis, and even the preparation of uninspired text-books, for the same reason. These things do not give the best preparation for and naturally do not lead to the highest university positions, though they do bring immediate financial reward; better far devote the time to some research if there is any in the teacher, and qualify for advancement in the college or university world. In education as in business, both the teacher and the institution may expect to get what has been paid for; if the teacher gives less than his best efforts he may look for less than a full reward, and the institution that seeks bargains in teachers will probably get something cheap—and nasty; if first rate results are to be achieved the price of first rate ability must be paid, allowing for a long and expensive preparation.

The bearing of this upon the question of research is evident; to cultivate the vitality of the intellect it must be free—free from anxieties as to the necessities of life, free to proceed in broad and deep channels, with all the incentives of intercourse with things intellectual and asthetic.

The story is told of a college teacher who was conspicuous at prayer meetings, that it was his custom in closing a lengthy petition covering a large amount of detail to say, "And now, O Lord, to recapitulate," and so on.

Permit me, then, in conclusion to summarize the points I have tried to present. In undergraduate schools research has a very important place as a stimulator and vitalizer of the teaching; it is, however, a secondary calling and should not be allowed to interfere with the main function of the teacher, namely instruction. The selection of men for such positions should be based primarily on their qualifications as teachers, and research should not be undertaken until a broad and deep foundation has been laid. The value of research, however, makes it most important that men capable of doing it should be helped in their efforts by the most favorable environment possible.

Plants and Man: Weeds and Diseases.

By Robert Hessler.

Indiana may be divided topographically into three parts—the southern hilly, the central rolling, and the northern part flat and wet. With the exception of the northwest, the whole State was originally densely covered with forests. The wet lands are being drained more and more and the land brought under cultivation. The soil is rich and produces heavy crops. It is surprising to learn that along the Kankakee first year crops require practically no cultivation, because there are no weeds. The next year a few come in; many are found by the third year, and after that farming becomes mainly a contest against weeds.

Bringing the land, whether densely forested or marshy prairie, into cultivation means displacing the native flora by foreign plants. These latter are of two kinds—those brought in purposely, cultivated plants of all kinds, and those brought in unintentionally, mainly weeds. Today most of our worst weeds are foreigners that have come from all parts of the world, especially from Europe, where for ages weeds have been fought and where certain ones have developed resisting qualities. Weeds are introduced in imported seed and also largely in hay and straw, used in crating. In waste places about cities where trash is thrown one may expect to find "new weeds." Some are also brought in by the railroads, the seed lodging on cars and falling off. Some are brought down by rivers.

When man cuts down the forests, plows the prairies and drains the marshes, he is disturbing the "balance of nature," and animals and plants move about to find new, suitable homes. Animals, of course, move about very freely; if their homes are destroyed they seek new ones; every botanist knows that plants do the same. That is, seed is carried about and germinates here and there; if conditions are favorable the plant may thrive, become re-established. If conditions are unfavorable it may perish very quickly, or it may persist for a year or two. Thus at present some of our native plants may be seen in localities where they had not been seen the year before or where they had not been seen for many years. I have a number of notes of such "moving about" plants.

When the old style rail fences were still common, many plants found a home along them; they perished under wire fence conditions. Some species may flourish for several years in wet meadows until a dry season destroys them. On the other hand, dry soil plants may flourish until a wet season drowns them out. Some will grow in ungrazed pastures. A number of other factors might be mentioned, but it will perhaps be seen from the above why some plants are constantly on the move. Some people, like plants and animals, are also constantly on the move. We need only think of the frontiersman who feels crowded when a neighbor moves within a mile of him. But this type has almost disappeared.

For a number of years I have been going along the railways and rivers looking for new arrivals. It is surprising to note the number of new weeds that have come in and are still coming. The railways in many respects furnish ideal situations. Here and there the right of way is level, alternating with steep, dry and gravelly embankments and wet ditches, occasionally there is a little pond; all these furnish a variety of habitats for different species. One destructive factor, however, must be considered—the annual weed cutting, as required by law. This means that many plants cannot thrive; they are cut off about seed time. (By the way, in my observations the railways alone observe the State weed cutting laws; it is practically neglected by road supervisors.) In the Proceedings (Academy of Science) for 1893 I published a list of thirty-five immigrants, of which at least half a dozen subsequently became common weeds, to be found throughout the county.

When I made a tour through the West, in 1905, I was surprised to note how free the Yellowstone Park is from our common weeds; I saw only one or two; evidently they are just beginning to come in. On the other hand, in traveling through the West, I saw a number of plants that I had previously found as adventive plants along the railways here at home. I felt like greeting them as old acquaintances. I saw many plants that I felt sure would come to Indiana in the course of time; in fact, as those who keep track of plants well know, new ones are appearing from year to year.

One year at Longcliff (the Northern Indiana Hospital for Insane) we had a large field of Crimson Clover, the seed having been obtained from a seedsman. In passing it one day I noticed a number of strange weeds and I at once came to the conclusion that this Crimson Clover had been imported from Europe. A few years later, while in Germany, I saw these same weeds in fields, and I then concluded that that seed had been imported from Germany. Moreover, while traveling through different countries in Europe I saw a number of weeds that I instantly recognized, because I had seen them at home as immigrants. There were many that I expected would come to Indiana in time—and they are coming; new ones appear every year. This summer, for instance, I found a little composite plant (Galinsoga parviflora)—it has no common name—about Longcliff. I had seen the plant about Berlin; the German botanies stated that it had been introduced from western South America. I have been wondering whether the plants at Longcliff had come from Germany or direct from western South America. It would be interesting to know the facts.

Several years ago I had as a patient an old farmer who came to an adjoining county when the country was first settled. He gave me many facts regarding early conditions; how the dense forest had to be cut down and clearings made; how the small truck patch required very little attention because there were no weeds, but in time weeds gradually came in and then the farmer had to fight weeds just as now in the Kankakee region. He also told of the coming in of pests and parasites of all kinds, including rats and mice, lice on animals, and blights and rusts on plants. He remembered when the peach blight first came, proving very destructive to peach trees. Unfortunately I kept no record of dates. I have often regretted that I did not make memoranda because these are matters for which we must rely more and more on what is already recorded in the books.

I live on a four-acre lot at the edge of town. In front of the house there is the lawn; in the rear along the river there is pasture; on one side there is the garden and on the other the orchard. Then there is the barn lot and also a neglected bit of land. (There are also two little plots, one for wild flowers and another for plants grown from seed brought from foreign countries.) There is a variety of habitats for plants and it is interesting to note how some flourish in one situation and some in another. The movement of plants is, of course, constantly interfered with by cultivation and weeding, notably in the garden and on the lawn. Some weeds are very resistent; in the barn lot, in spite of one or two cuttings every year, the Jimson weed and the Spiny Amaranth continue to grow; every year there are two or three plants. In the pasture again there is a small patch of Canada Thistles. This plot has been cut down and plants hoed down two or three times every year for the past eight years, and still the thistles are able to maintain themselves. The garden, of course, requires constant weeding. Practically all the weeds on the place are foreigners.

I just referred to a neglected bit of land, to an idle plot of ground. This at first, eight years ago, was covered with Blue grass and grazed. The number of plants that have come in since is something remarkable. Equally remarkable is the absence of common weeds; they seem not to get a start in the dense covering of Blue grass. Barnlot weeds are never found in that patch, nor some of the common garden weeds. Among the plants to appear were a number of trees and shrubs. Unfortunately, three years ago, a cow got in and many of the plants were killed off, but the way the shrubby and woody plants spring up would indicate that in a short time there will be a forest and light-loving plants will be wholly crowded out.

It is interesting to note how in the South, old exhausted cotton land when left to nature grows up in pine forests, Old Field Pine, but the wood has so little substance that a tree, when cut, will wholly fade away in the course of a year. It certainly takes a long time for exhausted soil to regain its strength and for trees worth while to again get a foothold.

Besides tramping along railways in search of new arrivals, I frequently take strolls about neglected parts of the city to see whether any new weeds have come in and what changes have taken place among those already present. One day last summer I started out from the heart of the city where there is no vegetation, no grass and no trees, because streets and sidewalks are everywhere paved. I went along one of the neglected streets which is either deep in dust or in mud. This street has practically no trees at all. Along the gutters were found growing a number of weeds, practically all foreign ones, that seem able to resist the dense clouds of dust that are deposited on them. The plants are white with dust, or rather grayish, almost resembling desert plants. I passed several waste lots covered with weeds, nearly all of European origin. I finally reached Shanty Town, where weeds flourish among the human habitations. The people themselves, like the weeds, were of the neglected kind. A little farther on I came to the railway shop, with its large roundhouse, where an immense amount of dense black smoke arises. Now, since our prevailing winds are from the southwest and west, the smoke, of course, blows off in the opposite direction. I was surprised to see that all the trees to the east in line with the smoke were dead, a number of dead trunks were still standing. When I first came here, fourteen years ago, there were a number of trees in that neighborhood. The black smoke killed them off. I was reminded of the hills about Pittsburg, which, as some of you may have seen, are denuded of trees on account of the smoke. The same thing is seen about some of the western smelters, where vegetation may be killed for miles, and poisonous deposits, especially of arsenic and copper, cover vegetation for a still greater area.

From the roundhouse I walked along the Wabash river, still looking for plants. The river is shallow and has a limestone bottom. Once or twice a year there is high water and that means to wash out everything loose before it. Seed brought down may lodge along the banks, especially at the flood lines, and every now and then new plants may be found. Some may grow near the water, but the next flood is very apt to wash them out. There are no gravel banks and some plants characteristic of other places are absent, as, for instance, plants found along the White Water river, where I used to collect, such as Saponaria officinalis, Polanisia graveolens and Cuphea viscosissima. The former, however, is to be seen more and more frequently above high water mark; the second, Polanisia graveolens, is occasionally seen; but I have not seen Cuphea at all..

Leaving the river I went west along the Wabash railway. This at first runs on a high fill with gravelly sides, later becoming level and prairie-like. Here in the course of time I have found a number of adventive plants, both European weeds and western species, the latter as a rule lasting only a season or two and then disappearing. Lower down I crossed the river on the railway bridge and followed up the Vandalia track northward. This runs over a deep fill. At one place the steep embankment was covered with cinders. I was immediately reminded of the cinder and lava slopes of Vesuvius. I was not at all surprised to see only a single plant growing among the cinders, the sheep sorrel. At once my trip up the Vesuvius came vividly to mind. I had gone up on horseback with three companions and a guide. At first we passed through towns and highly cultivated fields, but we gradually left these behind and came to a desert region of black cinders and lava, going upward all the time. Finally all vegetation disappeared, the last plant to disappear being sheep sorrel. On the descent I made a collection of plants, beginning with the first one to re-appear, Rumex[1]. Next came a shrubby Spartium. Gradually

[1] Whether the species is acetosella or scutatus I do not know. My Italian botany, moreover, speaks of a variety under the last species that grows among volcanic scoriæ.

other plants appeared, including a wild fig. Still further down came a small patch (one cannot say a field) of Lupines; probably that is the only cultivated plant that is able to thrive in the cinders. Next came a small vineyard and the cottage of a family. These people, like the plants on the slopes of the volcano, are in constant danger of being overwhelmed. Small plants are, of course, in danger on account of clouds of cinder dust, the wind at times being terrific.

All this came to mind vividly while standing at the cinder covered railway embankment. Then I mentally retraced my steps down to the river and to the plants that lead a precarious existence and are constantly threatened by high water. Then I thought of the people who live on the river front and especially on the little island, who, once or twice a year, are in danger of floods. Occasionally some must be rescued in boats. These, too, are reckless; prudent people likely would not be found under such surroundings. We all know how large cities with a river front are infested by a class of people known as "river rats," a highly undesirable class; human weeds, so to speak. When botanizing, we are frequently asked, What is the plant good for? One may also ask, What are weeds good for? Shall we also ask, What are some human weeds good for?

Continuing, I retraced my steps to the railway shops and the smoke. I recalled the sad-eyed women and sickly-looking children who exist in that atmosphere. The men, of course, are employed in the shops and I wondered how long they are able to hold out. It is well known that the city "takes it out" of strong and robust men—they soon fail. Large industrial cities have little use for a man after the age of about forty or forty-five. Now I knew that smoky air about the shops killed the trees and that only a few weeds were able to grow, and I wondered how long human life itself is able to endure under such conditions. Trees being fixed to the soil, live and die *in situ;* human beings are not fixed to the soil and so when they fall sick they generally remove to another neighborhood. If they are unable, on account of sickness, to pay the house rent, they are evicted and others move in. People removing from an unsanitary environment may regain health and perhaps again become self-supporting, but only too often they continue to fail and many die prematurely and the children become public charges. Who is to be blamed for premature deaths?

I further retraced my steps to Shanty Town. I recalled how the newspapers had frequent accounts of the prevalence of typhoid fever in that section, how shallow wells were infected. The water from the wells is used because it is clear. People prefer clear, sparkling water to muddy hydrant water, although the sparkling water may be veritable poison. Where does the blame for typhoid fever rest?

Still retracing my steps, I came to the neglected street with its weeds and with its corresponding class of people, going on to the heart of the city, with its lack of trees and full of sickly people. Then I compared or contrasted the West End of town with the East End. The West End is the home of working people, while the East End is occupied mostly by tradesmen and the well-to-do. Now our prevalent winds, as already mentioned, are from the west, and that means that the people in the West End get air from the woods and fields, while those in the East End get the smoke and dust from the shops and from the heart of the city. This may explain why the East End Wind has such an evil reputation, and why towns having the "West End" properly located are more desirable as places of residence. These remarks will be better understood when we consider that people, like herbaceous plants, but unlike trees, are more or less constantly moving about. Some plants come and go, they are seen one year and then disappear, perhaps to re-appear later; those finding the habitat favorable may remain permanently. Common weeds find conditions favorable almost anywhere and flourish, especially in neglected places. Shall we say that human weeds also thrive almost anywhere, and shall we say that people who are well-to-do and able to move do move out if they find that the "West End" has not been properly located?

The subject may be considered a little further. Several years ago a patient with whom I had often discussed things like the above told me about meeting an old friend who had just returned from the Saskatchewan. The man gave a glowing account of the large crops of wheat, and the large potatoes, beets and turnips, all growing without weeds; he told how healthy the people were, they did not even have the common ailments; he ascribed it all to the "wonderful climate." Climate nothing! my friend exclaimed; weeds and ills and diseases are absent because they have not as yet been brought in. They will all come in time; just wait a few years.

I might again refer to my old patient who had told me of early Indiana conditions and the coming in of weeds and pests and parasites of all kinds. He had also told me how healthy the first settlers were until malaria came in; then nearly everybody became sick. Life now assumed a serious aspect and there was much sickness until wet places were drained and chills and fever, that is malaria, became less and less prevalent; today malaria is a comparatively rare disease. At first, too, all the minor ills were absent. People did not even suffer from cough and colds. He told me how he used to go barefoot until the ground was covered with ice and snow and how he could wade through water that was cold enough to form ice and never "catch a cold". But he noticed that in time ailments and diseases came in. He referred to some affections as "new-fangled diseases".

When I called his attention to the analogy between weeds and diseases he readily understood. Before this was pointed out to him, however, he had expressed his belief that the race was degenerating. Referring to his long-lived family with many brothers and sisters, he said that all lived to old age, he himself being now in the eighties. He made the contrast between himself and his grandchildren, especially those living in the large city; he regarded them as "weaklings", requiring the attention of the physician more or less constantly. After I had pointed out the analogy between plants and man and weeds and diseases, he readily saw that his grandchildren were "weaklings" because they were living under an entirely different, an unsanitary, environment. The original Indiana inhabitants, the Indians, were healthy simply because not exposed to the cause of ill health and disease. People who are housed up in town are living hosts for the propagation of diseases, just as plants in hot-houses, which require constant attention to keep down diseases.

Moreover, the man himself was a living illustration of these changes, for he came to me on account of his own ill health, which he thought his home physician did not understand. He said the common country doctor is good enough for common country diseases, but "these here new-fangled diseases need men who have studied more". He referred to his own ill health as a "new-fangled disease", while as a matter of fact it was a very common ailment, one of the "diseases of civilization," nothing more than common catarrh. One did not have to seek far for the cause of his complaint. Until a year ago he always lived on the farm, very seldom coming to town; then he rented out his farm and removed to a small town, and now occupied a seat on the cracker barrel, that is, he spent much time loafing at the village store. Some of these stores are so dirty that they have required repeated notices from the State Food Inspector. Air conditions are especially bad. In a short time he began to react. He had catarrh and cough. On account of his cough he was inclined to be in the open air less and less and to house himself more and more, the very things he ought not to do. When I pointed out these things he promptly changed his mode of life and the reaction ceased. He was again "healthy".

It is undoubtedly true that all now common weeds and pests and parasites and diseases were restricted at one time to certain localities, from whence they have spread until they have become cosmopolitan. There are many data regarding first appearances. In our annual Proceedings, for instance, are a number of records for the first appearance of new plants and new animals, new in the sense of not having been found here before. The appearance of new diseases in the State is of course recorded in the medical journals, but imperfectly. The subject of the coming in of new pests and parasites and diseases is an important one and cannot be dismissed with a few brief paragraphs. I should like to give at least one illustration relating to the common potato.

The potato was carried from South America to Europe about the middle of the sixteenth century, and subsequently brought to our country, and now goes under the name of the Irish potato. Those of middle age can recall how, until in the seventies, the Colorado potato beetle was never seen in our potato fields. How this beetle came to us is an interesting story.

On the dry western plains there grows a species of spiny Solanum (S. rostratum), a near relative of the potato (S. tuberosum). This plant has a parasite, the beetle now commonly known as the potato bug. The plant grows very sparingly and that means that the beetle also occurs sparingly. A little reasoning will show why. If the bugs became abundant and would completely consume their food plant then they themselves would perish for want of food. On the desert the plants are far apart and many escape the attacks of the bugs and ripen seed, or if a single bug reaches a plant it will not injure it enough to destroy it.

Now when the common potato began its westward march it gradually reached the home of this beetle. The beetle found the new species more acceptable than the old and, since plants were close together, life conditions became easy and the potato beetle, now called the potato bug, at once increased enormously and traveled from one field to another, and in a short time overran the whole United States. I was surprised when in Germany to see the potato fields free from the potato bugs; authorities there are on the lookout; they are keeping it out as our own authorities at present are keeping out cholera, the plague, yellow fever, etc. It need scarcely be said that between the potato plant and the potato bug there exists the relationship of host and disease. The potato bug in its destrucive action on the plant may be considered the disease; it will destroy the plant just as the potato-rot destroys it. Before the cause of the potato-rot was recognized it was looked upon as a visitation, just as many of the human diseases were looked upon.

This fall the newspapers contained an occasional item regarding the spread of the potato-rot or potato disease. Just now the disease seems to be prevalent in some parts of Europe, destroying outright large potato fields in the course of a few days. Such an epidemic is a great calamity; it has been such in times past. It seems to be only a matter of time until the disease will reach our State. This disease seems to be at home originally in South America on the wild plants, but plants were few and far apart. When the potato is grown in masses this fungus disease naturally spreads very rapidly from one plant to another and from one field to another.

But it was noticed that after an epidemic a few plants survived. By taking these survivors and cultivating them a more and more resistant strain has been produced. One can thus speak of disease proof potatoes, just as we can speak of disease proof individuals, for instance, the negroes on the west coast of Africa, who are constantly exposed to malaria and are quite immune.

In the life of every individual there are periods that stand out. We need only think of such statements as "Before I went to college", or "Before I got married". Similar periods or landmarks stand out in the life of a community, as "Before we had paved streets" or "Before we had filtered water". We can likewise speak regarding the introduction of weeds and pests and parasities and diseases, as the days "before the potato bug".

Perhaps in tracing analogies one might mention the coming to our country of such diseases as Influenza and Asiatic Cholera. In earlier years, when the country was thinly settled, many escaped, and, on account of poor traveling facilities, diseases traveled slowly. Influenza has traveled more rapidly each time it appeared and attacked a greater number of people, because they are now living closer together. There are regions today, especially islands in the ocean, where some of our common diseases have not yet been introduced.

Our country was originally in possession of the Indians; European immigrants gradually displaced them. The early comers found a wilderness; they cut down forests and cultivated the land. They thrived exceedingly and built up towns and cities. Immigrants in large numbers have continued to come, but those who come today find all the land occupied. The poor immigrant no longer can or does settle in the country; he goes to the crowded cities where there is a demand for labor. Many of the present immigrants come from the open country; they are used to open air life, as their ancestors had always been. There has been little or no weeding out such as we find among people whose ancestors lived under city conditions. As a consequence, when these immigrants crowd into our cities—and of necessity they crowd into what are called slums rather than go to clean portions—they soon fail. Why is it that the children of the stolid immigrants are called neurotic?

Immigrants massed in cities need a change of environment. Country people thrive best under country conditions; many are wholly unadapted to city life with its many-sided contact with ill health and disease. Most immigrants are from country districts. No wonder the old farmer referred to his grandchildren as "weaklings", and believed that the race is degenerating, and no wonder physicians find children with all sorts of abnormalities and defects and that many are neurotic. Children, like plants, need room to grow; if massed together they, like plants, become stunted—in the end it is, of course, a survival of the fittest.

This brings up the very practical question, Why do we allow slums to exist? Why do we allow people to live under slum conditions? European cities are driving out their slums, but we have scarcely made any effort.

I referred to a plot of ground that is "going back to nature". Perhaps we can find analogies among men. In the first place, there are situations where we scarcely expect to find certain people. For instance, people who normally live in the slums are not to be found among the better class.

What do we mean by "the better class"? Do we not find a constant shifting about, some drop out, some rise and enter it? The old saying, From shirt sleeve to shirt sleeve, is very expressive. Very often, however, the dropping out is due to ill health.

Civilization, like farming and gardening, means a constant interference with nature. It is man against nature. When man gets back to nature old-time conditions never return, man again becomes strong and robust. We hear much of Race Suicide today. Perhaps under a more simple and sanitary life the race would again become strong and healthy and prolific, just as soil left to nature returns to its former condition.

I referred to the fact that many of our plants are constantly on the move. We see this exemplified again in man. Some people are moving all the time, one might almost come to the conclusion that the old-time home is disappearing. People will move from one house into another, from one street to another, from one town to another, alternating perhaps between town and country and from one end of the country to the other. One wonders why people move so much. One important cause in my observation is on account of ill health. Many move into another house or into another town in the hope of having better health. When they do find a congenial place they are apt to stay, just as plants and animals stay.

It is interesting to study the movement of population, of towns as a whole or of certain streets or of certain buildings in the heart of the city, say a large store or office or bank. "Office boys" are both from city and country; many country boys go to the city to "try city life". Some succeed but many fail. We hear of the successes but we usually do not hear of the failures, although there may be only one successful man to a hundred or several hundred failures. I am reminded of the remark of an old merchant: "The new boy who cannot stand the work of sweeping out the store and running errands is not apt to make a good business man", meaning in this case a storekeeper. The merchant knew this as a fact, he did not attempt to explain it. I offered him this explanation:

The new boy when put to sweeping may or may not react to dust influences. If he reacts there will be more or less complaint of ill health and in time he will drop out; if he does not react he may gradually advance and in time become a business man. The merchant whose name appears in the city directory year after year may be regarded as an immune, as an individual able to live under unsanitary city conditions. The directory does not mention the numerous failures. The successful business man in the city must be regarded as the survival of the fittest. He does not move about; he remains fixed because he is able to bear the unsanitary environment. This moving about is, of course, seen at its best in large manufacturing establishments, where there is a constant influx of "new hands".

Looking over the books on diseases of plants, one is surprised at the analogy between plant diseases and human diseases. One finds plant pathologists using the names of the human pathologist and the physician. They speak of "epidemics" and "endemics" among plants—those terms etymologically refer to people, meaning "upon the people" and "among the people". It seems rather incongruous to use such terms for diseases upon or among plants. But it is facts, not words, that scientists are after. Then there occur such names as chlorosis, icterus, atrophy, necrosis, and even cancer and consumption.

Plants are afflicted with diseases due to bacteria, to fungi (even to higher, flowering, plants), to animal and vegetable parasites of all kinds, to mites and worms, just as human beings. But, perhaps needless to say, the species are different. Although some of the common names current among physicians are used, yet the scientific names are wholly different. Another thing that impresses one on going through the books on plant pathology is the importance attached to cleanliness, as cleanliness about the orchard, destroying dead branches and leaves and keeping the ground and trunk clean, the necessity for spraying and fumigating, measures that physicians long ago learned but which the people are slow to adopt. That cities need as careful attention as orchards seems to be known to but few of the people. The old farmer must be told why his orchard does not flourish, why trees are sickly and ultimately die, just as many a community must be told why its people are sickly and why there is race suicide.

One day while botanizing I came across a field thickly overgrown with Iron Weed and Vervain. At one end it was wet and swampy, with pools of water. The farmer, who was plowing, overtook me. We engaged in conversation. I asked him why he allowed those weeds to grow. "The cows like weeds; they brush off mosquitoes and flies." He thought this sufficient reason for allowing weeds to grow. I pointed out how flies breed in his manure pile and that by giving a little attention the number of flies could be greatly reduced; that mosquitoes breed in wet places, as at the end of the field, and that with a little drainage the mosquito pest could be prevented; that with flies and mosquitoes absent there would be no need for the weeds; with fewer flies the cows wasted less energy in switching them and would give more milk; and in the absence of blood-sucking mosquitoes would gain in flesh. In the absence of weeds there would not be a constant cloud of seed blowing on to his cultivated fields and on to those of his neighbors.

He listened incredulously and when I finally told him how a certain mosquito transmitted malaria, he said, "Now do you really believe all that?" His own belief was that it was all nonsense.

What is the use of attempting to teach the old farmer? I thought. Perhaps if the school teacher told these things to the farmer's boys it would have some effect. They might see the need for cleaning up everywhere.

It is perhaps unnecessary to refer to the experienced florist or horticulturist whose knowledge enables him to tell from a plant's appearance that it is sickly and needs certain treatment, otherwise it will perish; or to the physician whose knowledge enables him to quickly recognize certain conditions in man and the need for a change.

Now resurveying the field, one comes to the conclusion that weeds and diseases and ill health exist mainly because we neglect to pay attention to cleanliness. When an epidemic threatens a large city then everybody gets busy and cleans up. There should be constant not periodical cleaning up. We should not allow the existence of waste places where weeds grow which will re-seed the whole country about. No matter how free from weeds a farmer or gardener may keep his own ground, seed are constantly brought in from the surrounding country. It takes a combined effort to fight weeds. As matters stand, farming and gardening are largely a warfare against weeds. The same is true in regard to communities and diseases. No matter how careful one individual may be the seed of disease constantly comes to him from those who are sick and diseased. He meets people on the street who come from neglected homes, from the slums where disease and ill health are endemic and from where diseases are carried to all parts of the city. By the way, nearly all the patent medicine testimonials we see in the newspapers are signed by people living in such localities.

We can look at the subject in another light. Many plants adapt themselves to their environment. Sensitive ones are readily killed off under conditions where weeds continue to flourish, just as many human beings are killed off or driven out where conditions are unsanitary. But we know to what extent some human beings can live under slum conditions; some must be regarded as human weeds, such as the Juke and Ishmael families. Like common weeds, they are undesirable. Cleaning up drives out the slums; moreover, slum children, if removed, in time may become desirable citizens.

Why is it that "human weeds" are given such an undue amount of attention, asylums are erected for them where they have the best of attention, where they live on to old age? Why must a man wait until he becomes insane or a pauper or a criminal before being housed under sanitary surroundings?[1]

Why does ill health flourish so widely? Why are there so many quack remedies, as those advertised in newspapers? The newspapers of some small towns are overcrowded with nostrums for common ill health. Where should the attempt to make a change begin?

One day I was telling a teacher that in Germany children are taken out into the country on certain afternoons to study nature, the valleys and streams and underlying rocks, the plants and animals; that boys make collections of plants and bugs, etc. Perhaps later when as adults they go out into the country they really "see" something. He admitted that that was all very nice but that it required the teacher himself to know what to point out.

He mentioned that some of our teachers had the pupils to study newspapers. But that occurs only in isolated instances; when we investigate we find that the editorial page only is read and studied.

Now the editorial page of large city newspapers as a rule is the only page free from offensive advertisements and reading matter, of accounts of murders and all sorts of things that do not elevate mankind. Likely the back of the editorial page is full of murder news and crude pictures of the murderer, his victim and the places where the deed was committed ; or the page is full of quack advertisements, of medical pariahs who claim to cure what no conscientious physician can cure; or of deceptive patent medicine advertisements for ills that no physician can cure, because they are a reaction to an unsanitary environment.

Now it would be a good thing for schools to study the newspapers, all their pages and all the papers, the high toned ones that leave comparatively little to be desired and the other kind called yellow. The re-

[1] This is not to be considered a criticism of our benevolent institutions; they are doing a good work, one in harmony with the spirit of the age. It took a long time to reach a high plane. Our leveling should be upward. As matters stand, the amount of attention given charitable institutions is wholly out of proportion to what is given worthy people not in institutions.

lationship of cause and effect should be traced. Do newspapers supply wants?

Is it reasonable to believe that the average newspaper publisher deliberately prefers to publish horrible murder accounts, nauseating and lying advertisements of all kinds, which he does not want his children to read? The editor himself has very little voice in the matter; he writes the high-toned editorials. It is the managing editor who must look for financial returns for the owner or rather for the publishing company; he gives the people what they want.

The matter of clean newspapers, clean cities and clean farms goes back to the community—there is room for the school teacher.

Every large city has a number of newspapers; some appeal to a certain class of readers only and go to certain sections of the city, some to the fine homes, some to the slums; others appeal to all sorts of readers.

Small communities may have only a single paper. By comparing the newspapers of small cities one can get a comparative idea of city conditions. Quacks and charlatans and patent medicine men do not thrive in clean communities.

The patent medicine men in their newspaper advertisements are still loud in their praise of our "valuable native medicinal plants." They evidently try to keep up the old-time belief that there is a plant for the cure of every disease.

In strolling about the country with a botany can, one frequently meets people who ask, What are the plants good for? Many have an exaggerated idea of the importance of plants, especially of common weeds, in medicine. Usually one does not attempt to explain. It may be said that as a rule plants play a very slight role in medicine today, only a few are used and then mainly to modify symptoms, less and less in the light of "curing diseases." Perhaps one can make distinctions between plants and their use, in this wise: Plants of least value, used to modify symptoms, are those that can be gathered readily, or which grow naturally as weeds, or which can be cultivated in gardens. Secondly, plants that must be looked for away from the haunts of man. One may say of these that if the individual in ill health will go and seek them out, using them under simple life conditions, likely he will regain health, as shown for instance in a little story by O. Henry, where the mere search for the rare plant in the mountains brought back health.

Just now we hear much about school gardening, having the children attend to a small plot of ground. We can readily see how a child may learn much regarding plant life, how the soil must be prepared, the seed planted at the right time, food and moisture supplied, and enemies of the plant held in check, weeds and animals of all kinds. The school boy learns that in proportion as attention is given to his plants and they are protected from destructive influences they thrive. By pointing out analogies between plants and man he can understand why man himself requires attention.

It is customary nowadays when any change is proposed to say, Teach it in the schools! Teach the Young! Just now there is a demand to teach agriculture in order to get away from old-time farming with its wasteful methods. Teach it in the schools! Teach the young! Now the same may be said regarding causes of common ill health. Teach it in the schools! Teach the young! The young learn readily and remember. Our schools already teach physiology but unfortunately it is largely if not exclusively a book study; often the book used is dry bone anatomy or dry as dust physiology and forced upon the children before they can grasp it. The new books on hygiene and sanitation are a great improvement but it is still only a teaching from books. If the teacher could take his pupils out and point out analogies between plants and weeds and diseases and if newspaper accounts were studied in the light of environmental influences, it would not take long until there would be a change for the better.

But in order that the teacher may be able to instruct the young, he must himself be taught. That means the colleges must take up the work, and since our Academy is mainly made up of college people, shall we say the work comes home to the Academy?

But, some will say, educating the people in regard to sanitary matters is work for the physicians, the physician should educate the people. That may be true theoretically but practically it is wholly false. Physicians treat sick people. Under present conditions that is all the people demand and all they are willing to pay for. Many have no use for the physician until they are actually disabled, sick or diseased, and then it may be too late to talk of education.

It may be asked, Why do not physicians at least call attention to these matters and to environmental influences, how people become sick and diseased on account of unsanitary surroundings? There are several reasons. First, a financial one: physicians like everybody else do not take up a work unless paid. Second, when physicians do advocate sanitary measures they are almost invariably accused of working to their own interests. As a matter of fact, however, practically all the sanitary improvements that have been made and are taking place are due to the efforts of physicians. To see how measures intended for the welfare of the people are antagonized by "peanut politicians," we need only consider what takes place in the legislature at every session, and how long it takes sanitary measures to pass. Why many physicians do not take an interest may be seen by what occurs when physicians object to the coming of quacks and charlatans who herald their wonderful abilities in the newspapers—almost invariably the newspapers take the advertising quack's part and oppose the home physicians. As a result many physicians do not concern themselves with the subject, they have all the work they can do and the "fly by night" does not interfere with their practice. Another, a third and very important reason is this: The physician as a rule belongs to the "weeded out" class. He is an individual who does not react to ordinary unsanitary environmental influences and because he fails to react is why he pays little attention to common ills and minor maladies. The reason why physicians belong to the "weeded out" class is simple: The boy who intends to become a physician requires good schooling; he may even be required to take a preliminary college course, get an A. B. degree, before he is allowed to enter medical college. Now many of our schools are very unsanitary and the bright boy reacts; he has ill health. He may drop out entirely or attend school only at intervals, but finally manage to complete the grades; then he is ready to enter high school. This is often located in the heart of the city under highly unsanitary surroundings. Trees may not grow but children are expected to. The ventilation of the school house is usually bad. The boy reacts promptly. He is more or less constantly in ill health and soon drops out entirely. Unless his parents are well-to-do and able to send him to a private school he is not apt to become a physician.

One can go a step further. Many medical schools are located in large cities under surroundings about as bad as they can be. Some young men who were able to complete high school (and we know there are some sanitary high schools where boys pass through readily) are now weeded out in the medical college. They fail to get a medical degree. The boys and young men who have "robust health" and are able to continue their education uninterruptedly are "the survival of the fittest." They can follow their profession in the heart of a city under the most unsanitary environment—and since they do not react they fail to understand the common ill health of their patients; they are apt to refer to some individuals as "imaginary ill." That may explain why the sick often go elsewhere and why faith and mind cures flourish. Now in regard to the latter it may be said that many individuals when they adopt some mind or faith cure change their habits, perhaps leading the simple life and remaining away from crowds. With this change comes about improvement in health.

The common doctor treats the common ill health and the common diseases of the common people, a fact pointed out by the Father of Medicine 2,500 years ago. It is rather anomalous that scientific physicians today should so largely be interested in well-defined diseases to the neglect of common everyday ill health. Every now and then we see a newspaper item under such a heading as "Conquering Disease." Newspaper reporters at times become enthusiastic and predict the conquering of all disease—but the less a man knows about the subject the more enthusiastically he may write. Be that as it may, we know that under present-day sanitation well-defined infective diseases are becoming less and less common every year. We need only think of what the introduction of pure water means to a city in such diseases as Asiatic cholera and typhoid fever. But although specific, epidemic, diseases are decreasing, common ill health is increasing, in spite of more and better doctors and better medicines—medicines that palliate but do not cure.

Now unfortunately there is no institution devoted to the study of common ill health, especially ill health dependent upon bad air conditions. The very common things of life are neglected—a fact which critics of the medical profession pointed out long ago. Until the people themselves take hold of the subject we need not expect much change.

Today we hear much regarding the role of well-equipped hospitals in city life. Many have an idea that the number of hospitals and their equipment are an index of a city's progress. The same individuals likely estimate a city's progress by the size of the smoke cloud overhanging it. As a matter of fact the opposite is true. A sanitary and well managed city has comparatively little use for hospitals, barring of course accident and surgical cases. Many hospitals in a community indicate much sickness and especially sickness of preventable kinds. What our cities need is not more hospitals but a thorough cleaning up, and shall one add that our cities should also prevent smoke clouds? Smoke means waste, besides destruction of life, as already mentioned.

The plant breeder is constantly seeking to eliminate the unfit. But man can not proceed on the same plan regarding his own kind. He does not wilfully seek the destruction of those not adapted. He tries to make the environment favorable so those who are apparently unadapted will survive. Nature is of course constantly weeding out the unadapted and the mortality rate of crowded cities is something terrific compared with life under simple country conditions. By giving the inhabitants of the large city pure water, good food, good air and clean homes the conditions for existence are at once made favorable.

Every now and then we read of cities that are seeking a slogan; what they want is one to indicate that they are growing bigger. A good slogan for nearly all of our American cities would be, "Let us clean up," or, "Not bigger but cleaner." Perhaps the best reputation that any city could acquire is "A city that cleans up." When the people once realize what cleanliness means our cities will be radically different from what they are today.

From what is said above it may perhaps be seen that the cries of Race Suicide, Back to Nature, and Back to the Simple Life have a good foundation.

Our Academy has a Committee on The Restriction of Weeds and Diseases ("Diseases" was added on my recommendation). For the past two years I have been chairman of this Committee but, I am sorry to say, when at the annual meetings a call for reports was made I had nothing to report. Perhaps I ought to explain. For the past year and a half I have been working on a manuscript, in fact on two manuscripts, dealing with common ill health and the need for cleaning up. One of these volumes is intended for the public and the other for physicians. The problem I am especially interested in as most of you know is to give the people good air, air free from dust and smoke. Until these two volumes are out I do not feel like taking up the subject publicly. But I feel that this is a subject that should be taken up by the Academy, perhaps at first in a small way, gradually enlarging. We must interest the people. Sanitation can not be forced upon them. It takes time. We need only think of measures to limit the use of alcohol and tobacco. If there is no public sentiment in a community laws are not enforced, and a law that is not enforced is worse than none at all. Many are skeptical about the present generation but expect much from the coming one. Perhaps the matter is largely in the hands of the school teachers, and since the Academy is made up mainly of men who instruct the teachers it comes back to the Academy.

In concluding I may say that we have a Federal Department of Agriculture which gives attention to plants and weeds, to animals and pests and parasites of all kinds, but it neglects the farmer himself and his children. We need a Federal Department of Public Health, a Department which will study the needs of the people and give them information regarding health and ill health and disease just as the Agriculture Department now gives information about animals and plants.[1]

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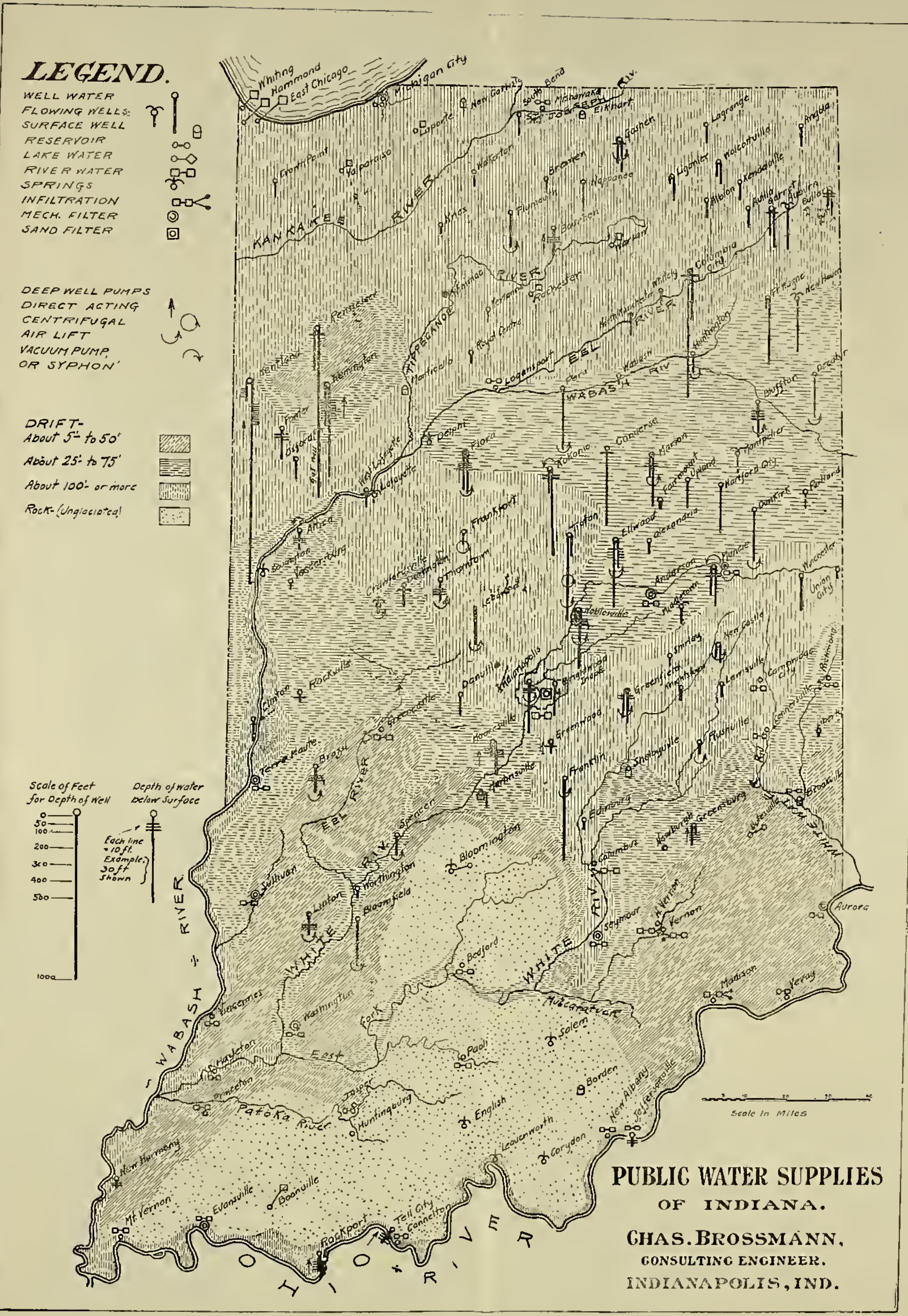
[1] A resolution endorsing the establishment of a National Department of Public Health was passed unanimously.



LEGEND.
WELL WATER
FLOWING WELLS
SURFACE WELL
RESERVOIR
LAKE WATER
RIVER WATER
SPRINGS
INFILTRATION
MECH. FILTER
SAND FILTER
DEEP WELL PUMPS
DIRECT ACTING
CENTRIFUGAL
AIR LIFT
VACUUM PUMP OR SYPHON
DRIFT-
About 5' to 50'
About 25' to 75'
About 100' or more
Rock-(Unglaciated)
Scale of Feet for Depth of Well
Depth of water below Surface
Each line = 10 ft. Example: 30 ft shown
Scale in Miles
KANKAKEE RIVER
WABASH RIV.
EEL RIVER
WHITE RIVER
OHIO RIVER
WABASH RIVER
Indianapolis
Terre Haute
Evansville
Lafayette
Logansport
Michigan City
PUBLIC WATER SUPPLIES
OF INDIANA.
CHAS. BROSSMANN,
CONSULTING ENGINEER.
INDIANAPOLIS, IND.

Water Supplies of Indiana.

By Charles Brossmann.

More than 60 years have passed since the first Municipal Water Works of the State were installed at Madison, Ind. Since then, many plants have been erected. Our complex life and increasing population has necessitated new methods of living and caused new demands; the most important among them being good water. At present there are few towns of any size that do not have public water supplies.

In the year 1890 there were about 50 plants in this State and at the present time there are over 150 plants. It has not been possible to get information on all plants, but the figures represent a very healthy growth. The town pump and historic oaken bucket are being abandoned, and the more convenient and usually safer public supply is being gradually adopted. The supplies for public use as a rule are more carefully selected and situated and taken from a source less liable to contamination than are the individual surface wells of the householder.

The installation of a water works plant usually is followed by the installing of sewers, which is a great asset to the sanitary conditions of any locality.

Of the water works here charted approximately 65% are well systems, 15% river, and the balance springs, flowing wells, lakes, open wells, etc. About 60% of the plants are municipal plants and the balance operated by private companies.

The arrangement and method of charting the supplies has been undertaken with the hope that it may be the start of a more complete investigation and record, and that such contributions or additions may be made from time to time as will increase its value as a water supply record of the State. The author's studies in this line have taken into consideration the mechanical equipment of the plants using these supplies, but it is not the intention to go into this part other than to show on the map the method of procuring the subterranean supplies of water. The map of the State before mentioned shows the various sources of supply, the method of procuring same, and how they are prepared for use. The well supplies are shown, giving the depth of well, the level of the water (where it has been possible to secure same), and roughly the depth of glacial drifts as found in that section; the drift depths are as given by the United States Geological Survey.

North of the Wabash river the depth of drift is approximately 100 feet or over, the best wells being usually in this material. Quite a portion in the western part is the region of extinct lakes. An interesting comparison occurring in this extinct lake region, is the supply of Kentland. This town formerly had its supply from a well about 1,200 feet deep, the water having a strong odor of sulphur. The water in this well stood 72 feet below ground about six years ago. Last year it was 120 feet below ground when pumping, and owing to this great lift caused much trouble and expense in pumping same.

This year a new plant was installed at Kentland. A new site was selected about one-half mile from the old well. The wells were drilled to a depth of 87 feet when rock was encountered. The last 15 feet of the well was in white sand, and produced a clear sparkling water without taste or odor. This installation is of interest as it shows such a difference in the two wells and their product.

From the south of the Wabash river to the Ohio the drift varies from 5 to 100 feet in depth, except for a triangular shaped section, with the apex below Martinsville, which is practically in the rock section. The water works of English in this region are of more than passing interest, as the supply of the town is secured from an elevation high enough to give pressure without pumping.

It will be noted on the map, that of supplies shown in the rock country, the majority are springs or river supplies. The procuring of water in quantities sufficient for public use is in some parts of this district a very difficult problem, especially in dry seasons.

The water of the State can be divided into two main classes, surface and subterranean supplies. The surface supplies comprise the river, lakes and large surface wells or reservoirs and may be divided into the filtered and unfiltered classes. The subterranean waters consist of the deep wells, flowing or unflowing, and springs.

The most noteworthy characteristic of the surface waters is that they are as a rule softer than the well waters and after filtration usually make a very satisfactory supply. The well waters as a rule are harder and in numerous places give trouble from this cause, often making it impossible to use them satisfactorily for steam purposes.

Muncie uses well water. The raw water is heavily impregnated with iron which is treated by aeration, which puts the supply in a satisfactory condition.

An important condition found in the well supplies has been the information secured showing the lowering of the water level at various places. This occurs in a number of localities, some of which are herewith mentioned.

Towns.	
Kentland (old gas well)	48 feet drop in 5 years.
Elwood	40 feet drop in 12 years.
Greensburg	40 feet drop in 10 years.
Muncie	28 feet drop in (time not given).
Remington	8 feet drop in 10 years.
Marion	6 feet drop in 20 years (cause of the fall at Marion is given as due to waste from other wells).
Butler	4 feet drop in 10 years.
Bourbon	3 feet drop in 8½ years.
Linton	Some wells show 30 feet drop in 6 years.
Kokomo	Some wells have dropped 15 feet since 1895.

It is a long step back to the time when there was nothing but water over what is now Indiana; but now, over that same area the procuring of water is an engineering problem of some importance.

The gradual receding of the water from the inundated area took place, of course, through a great length of time, but even after the waters became confined to their individual channels, such as our present day rivers, the point of saturation of the earth has been lowered by natural and artificial causes, such as deforestation, large drainage and reclamation works and the drainage of farm lands. Records from the weather bureau show that the rainfall for the past twenty years has not decreased. The question of run-off, however, is more important, as this undoubtedly has been, and is becoming more of an important factor each year.

A systematic method of recording all supplies in the State and tabulating all data pertaining to old as well as new supplies would be of great value. This could be best undertaken by one of the departments of the State and this information is here presented as a nucleus for the same.

A Building for the Department of Practical Mechanics at Purdue University.

By M. J. Golden.

The building was designed for the purpose of providing laboratories in which to teach students of engineering, shop practice and mechanical drawing, and is meant to accommodate three hundred students in the shops and three hundred students in the drawing rooms at one time. The mechanical drawing taught is the usual elementary drawing that precedes engineering design, and includes descriptive geometry. The shop practice includes manual training and practice in the methods employed in manufacturing where special tools and labor saving devices are used; this involving arrangements in the shops for demonstration work before groups of students.

The principal conditions necessary for the proper carrying on of such

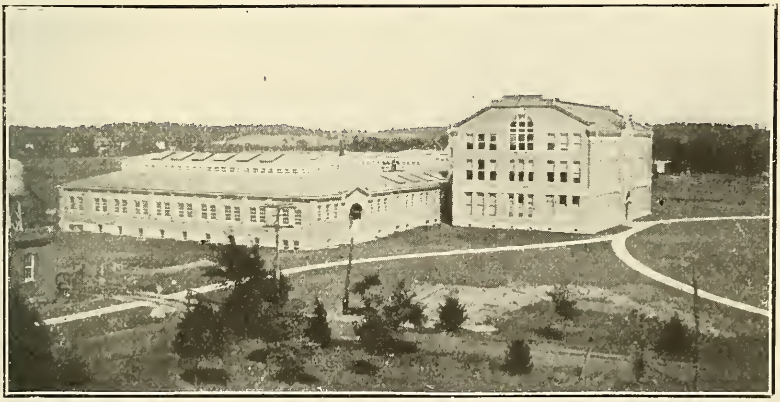
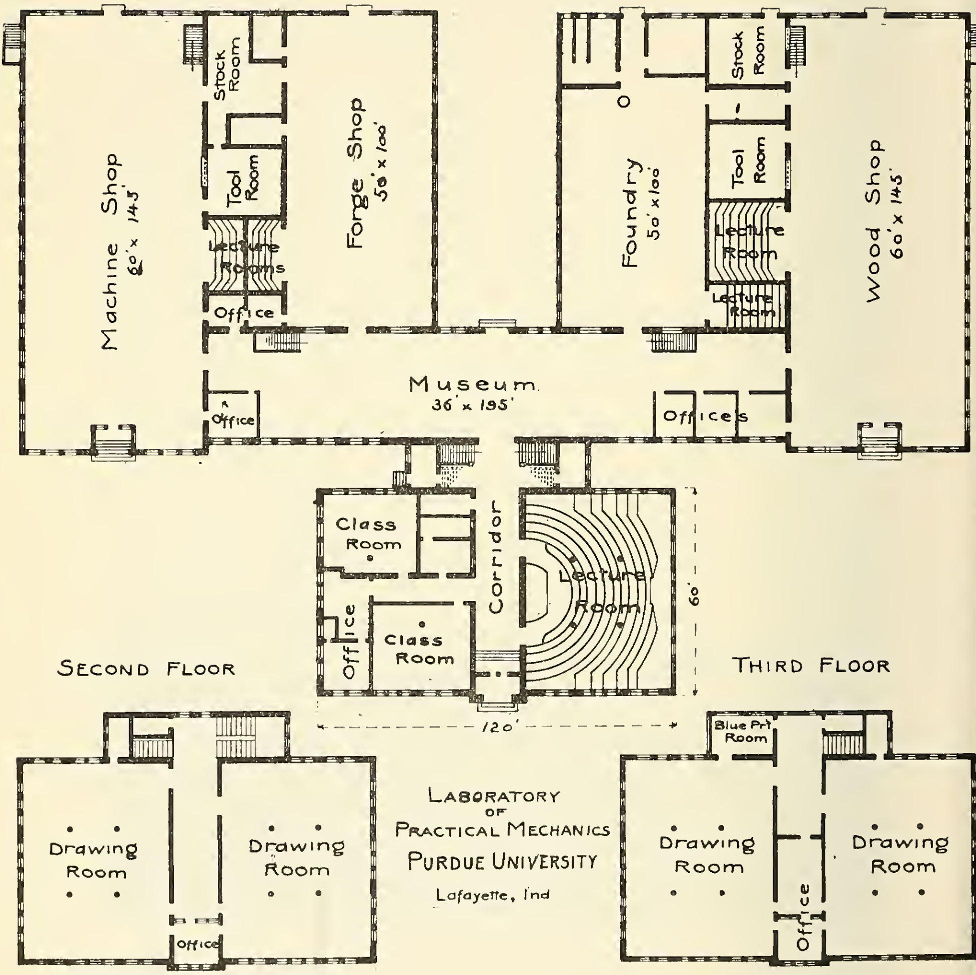


Fig. 1.

work are ample light, proper ventilation, and careful regulation of the temperature.

The building is of common brick with stone trimming and the design was purposely made to be as simple as possible, as befits a structure for such purpose. The general appearance is shown in Fig. 1.


Machine Shop
60' x 145'
Stock Room
Tool Room
Lecture Rooms
Office
Forge Shop
50' x 100'
Foundry
50' x 100'
Stock Room
Tool Room
Lecture Room
Lecture Room
Wood Shop
60' x 145'
Museum
36' x 195'
Office
Offices
Class Room
Corridor
Lecture Room
Office
Class Room
60'
120'
SECOND FLOOR
THIRD FLOOR
Drawing Room
Drawing Room
Office
Blue Prt Room
Drawing Room
Drawing Room
Office
LABORATORY
OF
PRACTICAL MECHANICS
PURDUE UNIVERSITY
Lafayette, Ind

It consists of a three story front in which are the drawing rooms, lecture and class rooms, and offices, and a series of one story rooms for the shops; the separate shops are bound together and to the front by a large corridor that serves also for museum purposes.

LIGHTING.

Considering the lighting first, the effort was to have as much lighting from the sky as possible; and as the large area of the roof made a troublesome accumulation of snow probable at times, a sloping roof with small pitch was taken and large skylights used to give the desired openings. These openings are glazed with a maze glass that is reinforced with wire netting, and this has been found to give a light distribution that is satisfactory. The saw-tooth form of roof was discarded in the design because of the possible snow accumulation in the valleys. The skylights are used in all the shops and for the drawing rooms in the third story of the front. In the rooms in the front where skylighting cannot be used, the windows are made to extend to the ceiling and to be as large as safe wall construction will permit.

The artificial lighting is principally by 60 C. P. incandescent lamps. In the drawing rooms these are arranged in groups of four close under a whitened ceiling. This arrangement is used also in the lecture rooms, the forge shop and foundry. In the machine shop the arrangement is supplemented by individual lights at the ends of arms made of flexible tubing, and in the wood-working room, mercury vapor arcs are used for the ceiling lights, with the individual lamps at the benches and lathes. In the wash and toilet rooms the light is distributed by individual ceiling lamps.

HEATING AND VENTILATION.

It was considered desirable that the heating and ventilating be by separate systems. The heating is done by radiation from steam heated radiators that have automatic control. These are coils of pipe that are suspended from the ceiling in some portions of the shops and wall radiators in other parts, and in the front portion of the building. The steam is generated in the central heating plant of the University, and is brought to the building in covered pipes in a tunnel.

The ventilation is accomplished by taking air from outside the building and after passing it over steam heated pipes in a chamber in the basement, where it is tempered to 67° F., forcing it through ducts in the walls and distributing it over the building. In the shops the distribution is through sheet metal pipes that are suspended against the upper portion of the side walls. The temperature is controlled by a regulating device in the heating chamber. By this scheme the ventilating apparatus can be closed to any portion of the building not in use. It may be used also as a supplementary heating system in severe winter weather.

POWER.

The electric current used for power and lighting is generated in a plant that is about three hundred yards away from the nearest point in the shops. It is of the alternating kind and is brought to the building at a tension of twenty-two hundred volts and is then stepped down to two hundred twenty volts in a transformer that is placed just outside of, and in the rear of the shops. The portion used for power purposes is carried to a number of small motors that run groups of the machines or that run individual machines: there are seventeen groups in all besides the individually driven machines.

In the wood working shop it has been possible to place the motors in the basement, and this is especially desirable in wood working, as it tends to freedom from dust. This was not possible in the machine shop, because of the design of the driving heads of ordinary machine tools.

The general arrangement of the building is shown in Fig. 2, where the floor area devoted to the various purposes is shown, also.

Adjacent to every one of the shops there is a room for demonstration purposes. This is arranged so that a machine may be conveyed from its place on the shop floor and used during the exposition of its purposes. Power for this purpose is brought to these class rooms; and to furnish current for the projection lantern in the large lecture room, there is a separate set of wires from the power house, bringing a direct low tension current. This low tension current is carried at one hundred ten volts.

CONVENIENCES.

The basement under the main corridor has the locker and toilet rooms; a battery of forty wash basins supplied with hot and cold water, and rows of metal lockers are arranged at each end. There are individual lockers for eight hundred fifty students, in which they keep their work clothes. In the shops there are also separate lockers for eight hundred fifty students, in which the material on which they are working is placed when not in use.

The drawing rooms are furnished with corresponding lockers and other facilities for the apparatus used in drawing. In the third story are two rooms for blue printing and corresponding work. One room is arranged for sun printing and has sheets of plate glass in an exposing wall on one side. There are the usual printing frames. The other room has no outside wall and is fitted with a blue-printing machine in which exposure is made to a rise and fall electric arc. The washing and drying of the prints are done in the sun printing room.

There are two dark rooms for photographic work.

The Cycle of Subterranean Drainage as Illustrated in the Bloomington, Indiana, Quadrangle[1].

By J. W. Beede.

The Bloomington, Indiana, quadrangle[2] is the first topographic map to be completed in the cave region of Indiana. It is fifteen minutes square with contour interval of twenty feet and scale of 1/62,500, or about a mile to the inch. Careful inspection of the field shows it to be remarkably full and accurate in detail.

While the cycle of subterranean drainage, as here presented, had not been discussed between us, yet all the various phases of it have been discussed and similar conclusions independently reached by both Professor Cumings and the writer as the result of tramps and class excursions over the cave regions of Indiana. The cycle has also been given as lectures, illustrated with lantern slides, in our classes. This paper has also had the benefit of Professor Cumings' criticism.

The physiographic history of the Bloomington region is such as to make this map very interesting, both for the remarkable preservation of the older geographic features and for the recent modification of them. Not the least interesting, nor the least important of these, is the subterranean drainage. Indeed the fine preservation of the older features is due to the fact that the water has, figuratively speaking, soaked into the old peneplain much as it would into a sponge, confining its work to the solution and honeycombing of the rocks beneath the surface instead of concentrating its energies cutting it into ridges and valleys.

The whole of the quadrangle, excepting, perhaps, the northwest corner, lies in the driftless area of Southern Indiana. The larger streams, except

[1] The title of the paper as shown in the program was "Features of Subterranean Drainage in the Bloomington Quadrangle." After the title had been sent in it was realized that it would be impossible to treat the subjects in mind intelligently without outlining the cycle of subterranean erosion. This outline, of course, overshadows the minor details intended to be covered in the paper, and hence the change in the wording of the title.

[2] Price five cents. Apply to The Director, U. S. Geological Survey, Washington, D. C.

Clear creek, were effected by glacial waters which were one of the potent factors in producing the beautiful terraces of Beanblossom, Salt, Richland and Coon creeks. However, it is with the subterranean drainage that we wish to deal at this time.

GENERAL CONSIDERATIONS.

Before discussing the details of the underground drainage of the Bloomington region it is necessary to discuss some of the general features of the development of subterranean drainage under various conditions. Underground drainage is developed in two ways:

1. In a region of very soft, porous rocks, where jointing and bedding may play a somewhat minor role, the channels are determined to some extent by the varying degree of porosity of the rocks through which the water percolates. Under such conditions the caves are apt to be less regular in their forms and their courses less angular than would otherwise be the case. This also has a marked effect upon the origin of the sink-holes and cave openings. Under these conditions the sinks may be formed where the rock is somewhat more porous or where there was a slight depression originally. These factors are modified by the proximity of channels beneath the surface. In such cases, as has been pointed out by Sellards[3], the sinks first appear as "cave-ins" of the soil and rock structure, the sink being first a hole of greater or less size, sometimes being larger below than at the surface. That is, the hole may be conical or "jug-shaped," as suggested by Eigenmann[4]. The caves of Cañas, Cuba, are of this type. Sinks of this kind are formed most abundantly where the surface of the region is but little elevated above tide or general drainage level and the caves or channels are close to the rock surface so that it is easily undermined. In cases where the caves are far beneath the surface the sinks will be determined—in the absence of surface irregularities—by the location of the more porous spots in the rocks near the subterranean channels and will be developed by solution from the top downward. It may be remarked here that the joints in some of the Cuban caves are inconspicuous.

2. The other condition under which caves are formed and free underground drainage developed is in the firmer limestones, usually well above sea level and the major drainage lines. The denser the limestone the

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[3] Science, XXVI, p. 417, 1907. More fully, Bull. 1, Fla. Geol. Surv., pp. 49-57, 1908.

[4] Bull. U. S. Fish Comm., 1902, pp. 211-236.

smaller the percentage of pore space, and the thinner the beds the greater is the tendency to form sinks and caves and the more sharply angular are the subterranean drainage courses. This is excellently illustrated in the cave region of Indiana. The Mitchell limestone is very dense, thin bedded and impervious for a limestone and is broken into small joint blocks. Here the subterranean flow is largely confined to the joints and bedding planes, thus concentrating the solution effected by the water to the immediate channels through which it flows. In this way channels are produced and enlarged with maximum rapidity.

On the other hand we may contrast this condition with that of the Salem limestone lying immediately beneath the Mitchell limestone. The Salem is nearly devoid of bedding planes, a rather soft and quite porous limestone, through which the water percolates with relative ease. The result is that caves in the Salem limestone are very rare. When they occur,

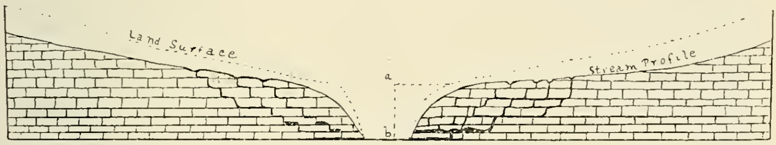

Fig. 1. Diagrammatic illustration of incipient subterranean drainage. The main stream is entrenched and the tributaries out of adjustment pitch over rapids to join it. Underground drainage has started through the joints. The vertical dotted line a b represents the original unbalanced static water head which started the circulation.

as at Mays cave, they may be formed by a cave passing down from the Mitchell limestone into it to reach the surface nearer the drainage level. The lack of frequent bedding planes is a strong contributory factor to this condition. Aside from its structure the opportunities for the formation of subterranean channels are as good as in the Mitchell limestone.

Again, the Harrodsburg limestone, lying immediately below the Salem limestone, is harder, less porous, more highly jointed and thinner bedded than the Salem and shows a correspondingly greater tendency to develop underground water channels. The Mitchell limestone possesses the extreme of these conditions and the extreme development of underground channels.

THE SUBTERRANEAN DRAINAGE CYCLE.

In either a coastal plain or an interior region which has been thoroughly baseleveled and reëlevated, what drainage there is to begin with is surface drainage. It remains surface drainage until the rapids of the larger streams have deepened their valleys well across the plain, leaving their tributaries out of adjustment with them. At this stage underground drainage first takes place to a considerable degree. The rocks are saturated with ground-water and at the level of the larger streams is under an unbalanced static head equal to the difference in elevation of the surface of the tributary, and of the water table between the tributaries, and the

Fig. 2. Section of a funnel-shaped solution hole (enlarged joint) in limestone, illustrating the origin of solution sinks.

main stream. As this is slowly drawn off more is supplied from above and a subterranean circulation is begun. The development of sinks goes along with the development of the subterranean drainage channels. The cross-joints most favorably situated with respect to free circulation below and supply from above, soon begin to be enlarged by solution. This solution is most active where the water first comes into contact with the limestone and the upper part of the opening will be dissolved most rapidly, resulting in a funnel-shaped hole. The larger this funnel becomes the more water it collects and the more rapidly it widens at the top and the larger the sink becomes. In this way the sinks develop at the same time that the subterranean channels do and in a region of mature sink topography where the channels are well below the surface, as in the Indiana

Fig. 3. A more advanced stage of subterranean drainage than No. 1. Sinks have developed and all the water of the stream passes beneath the surface and enters the larger stream as a great spring. It may be considered a sort of vertical self capture, a common occurrence. The underground channels have become enlarged and subterranean drainage has worked headward along the stream. At this stage the sinks will be developed over considerable of the surrounding land surface. It may be regarded as approaching maturity.

region, probably ninety-five per cent. of the sinks are formed this way.[5] It is certainly true of the Bloomington region and all the Indiana region as far south as Wyandotte that has come under the writer's notice. In some cases a sink may cover many acres and be as much as a hundred feet deep.[6] The first surface indication of the sink is frequently the collapse of the soil into the funnel which has been dissolved in the surface of the underlying rock. This has probably given rise to the popular notion that sinks are usually formed by the collapse of the roofs of caverns.[7] Incipient

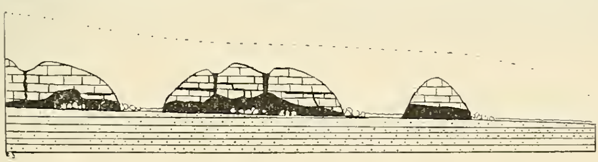

Fig. 4. An ideal section, similar to Nos. 1 and 2, in old age. Natural bridges are developed, much of the roof of the subterranean channel has collapsed, revealing the underground stream, and the mouth of the cavern has retreated by collapse and erosion. Dotted line indicates the old land surface.

[5] See Blatchley, 21 Ann. Rep. Ind. Dept. Geol. Nat. Res., p. 133, 1896.

[6] For a discussion of the solution of the Indiana limestones, see Cumings, Proc. this Acad., 1905, pp. 85-102, 1906. Caves, F. C. Greene, idem, for 1908, pp. 175-183, 1909.

[7] This does not seem to apply to the caves of Florida and some regions of Cuba where the channels are very near the surface and the roof soon becomes so weakened that it gives way, and the extreme porosity of the rocks does not concentrate the solution to the joints to produce solution sinks.

sinks and slightly developed underground drainage may be considered as characteristic of the youth of subterranean drainage. There will be no collapse sinks at this stage.

In the course of time the water of some of the streams may all pass below the surface and issue as great springs or subterranean streams in the channels of larger streams or in their own channels below where there may have been rapids or considerable fall in the beds. As time goes on this sinking of the water progresses headward along the stream, reducing

Fig. 5. Abandoned bed of Lost River, near Lost River station, north of Paoli, Ind. During floods this channel contains water. It is twelve miles long. The valley is very broad, with indistinct bluffs.

more and more of its course to underground drainage. The distance which streams may flow underground before reappearing at the surface depends upon the physical conditions in which they are placed. The distance that they are now observed to flow beneath the surface depends also upon the stage in the cycle of erosion in which they happen to be. Thus, in the Bristol-Standingstone region of Tennessee and neighboring country the distance seems to be about a mile. Lost river, in Indiana, flows about six miles in a direct line, or about double that distance by the old channel, before reappearing. Perhaps Lost river should be regarded as being in a somewhat later stage in its cycle than those of the region just mentioned, since there is evidence that collapse has brought the present stream to the surface for some distance below the "Gulf" where it now escapes.

The collapse of the mouth of the cavern is brought about by the increased width and height due to solution and abrasion, the fall of slabs

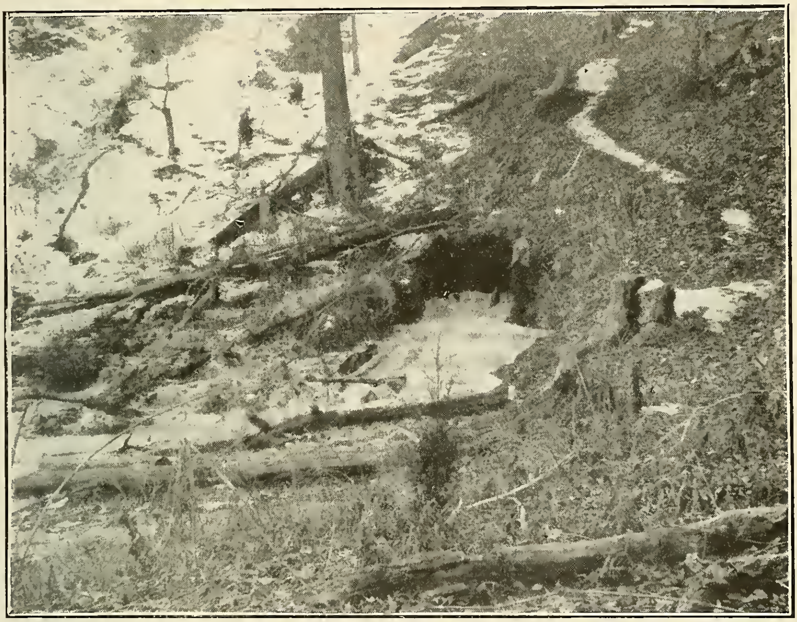

Fig. 6. Stony Spring. Bloomington waterworks. During freshets the water flows out all around the foot of the hill shown in the picture and even farther to the left. The cavern containing the stream is here collapsed, blocking the outlet. When the cave fills with water it breaks out wherever it can find an opening. The water comes from the former drainage basin of Indian Creek and now enters the head of Clear Creek.

from the roof and by the lowering of the channel until the roof, unable to support itself, finally falls. This collapse of the lower portions of caverns bringing more and more of the subterranean stream to light may be, and frequently is, going on at the same time that the upper reaches of the stream are being converted from surface into subterranean drainage. This is true of nearly all the largest outlets of subterranean drainage in the Bloomington region. Stone spring at the Water Works, Shirley spring and Leonards spring, southwest of the Water Works, and Blairs spring, just northwest of Stanford Station, all show this phenomenon, while the upper parts of the streams feeding them are still being more thoroughly taken under ground. A good example of this is seen in the sinks just east of the County Farm. The old sink is located in the angle of the road, while the stream now passes beneath the surface fully a quarter of a mile upstream to the northwest. Only the flood water now finds its way into the deeper sink below. The collapse of the mouths of caverns is excellently exhibited

Fig. 7. Shirley Spring (East Spring), S. E. of Leonard Schoolhouse. The outlet of the stream entering the sinks east of the Poor Farm and the intervening sinks. For abandoned, higher cave, see Fig. 30. The condition of collapse is similar to that shown in Fig. 6.

in the Shawnee caves east of Mitchell, Indiana, while Lost river shows it still better. In both cases the roof has collapsed back for considerable distances and in each there are cases of collapse above the mouths of the caverns where either the cave or the stream is brought to light.

When this stage of the drainage has been reached sinks have developed over most of the region on the interstream spaces as well as near the streams and most of the drainage is subterranean in the stricter sense of the word. This stage shows the large sinks near the larger drainage lines, surface or subterranean, and the smaller ones farther from them, as is illustrated in the plain southwest of Bloomington. When this stage has been reached—with sinks well developed over most of the region and collapse has begun at the exits of the cave streams—a region may be regarded as in its maturity. It is only after the mature stage of the cycle has been reached that sinks, due to the collapse of cave roofs, begin to appear in considerable numbers, and natural bridges, due to collapse of the cave roofs above and below a given point, begin to be developed. Solution

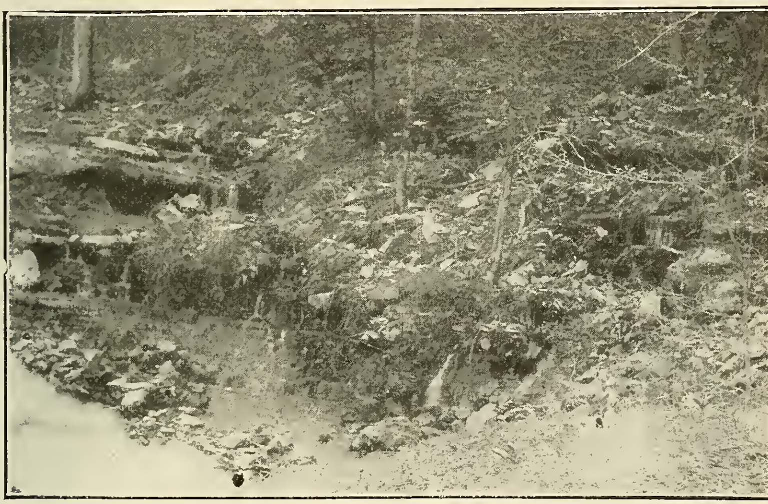

Fig. 8. Spring at Leonards Mill (house in deep gulch south of Leonards school), showing similar features as preceding. Note water escaping all around the foreground. A portion of the water from the main spring is shown in the extreme lower left corner of the picture. The outlet for the sinks south and northwest of Leonards school.

sinks that happen to be located above caverns may be, and frequently are, transformed into collapse sinks in the latest stages of subterranean erosion.

When these features of collapse become prominent and much of the drainage has been brought to the surface again and collapse sinks are numerous, old age has been reached.

The valleys produced by the collapse of caverns and the transformation of subterranean drainage to surface drainage have a characteristic form that at once distinguishes them from ordinary drainage valleys. They are rather sharply U-shaped, with steep sides like a young valley but with a fairly wide bottom and a blunt, steep termination at their heads. In these respects they resemble miniature glaciated valleys. When well developed they may be shown on accurate topographic maps. Surface erosion begins modifying them at once and finally obliterates the evidence pointing to their origin. The final result of the subterranean drainage cycle is thus a surface drained peneplain.

There is a lack of subterranean drainage in the old age stage of the cycle in the Bloomington region. The whole sink hole plain of Indiana

Fig. 9. More distant view of Leonard's Spring. The main spring is seen back of the stone dam. The water is issuing from a hole in the dam in the middle foreground. Note the steep, blunt end of this collapsed-cave valley.

may be considered as in its maturity. However, there are exposed in the sides of the monadnocks west of Harrodsburg certain old solution channels which probably represent the very heads of the subterranean channels of the preceding cycles of erosion. Indeed it is not improbable that the streams tributary to Clear creek on the west and north of Harrodsburg owe their present position in some degree to the location of former subterranean creeks. These in turn were profoundly influenced by the position of the previous Tertiary(?) surface streams.

In a coastal plain the details of the cycle will be somewhat different, but the essential features will be similar. The differences will be due to the physical characters and structure of the rock, the lack of previously established drainage lines and the relatively low elevation above sea level.

Fig. 10. Leonard's Spring, S. W. of Bloomington, showing valley with spring in distance.

PIRACY.

At the time when the subterranean drainage is at the maximum it is subject to the same accidents as surface drainage, except that the *modus operandi* is different. Subterranean piracy falls under two distinct heads, the capture of one surface stream by another through subterranean drainage, the easiest form to observe, and the capture of one subterranean stream by another. In each case there are minor varieties of capture such as one tributary by another, and self capture. Indeed these are probably much more common than the capture of one surface stream by another.

If a surface stream flows a long distance over a rather gentle grade to reach a certain level while a competitor flows a short distance to reach a similar level it may capture the headwaters of the former through subterranean drainage, leaving the divide between the valleys intact. This

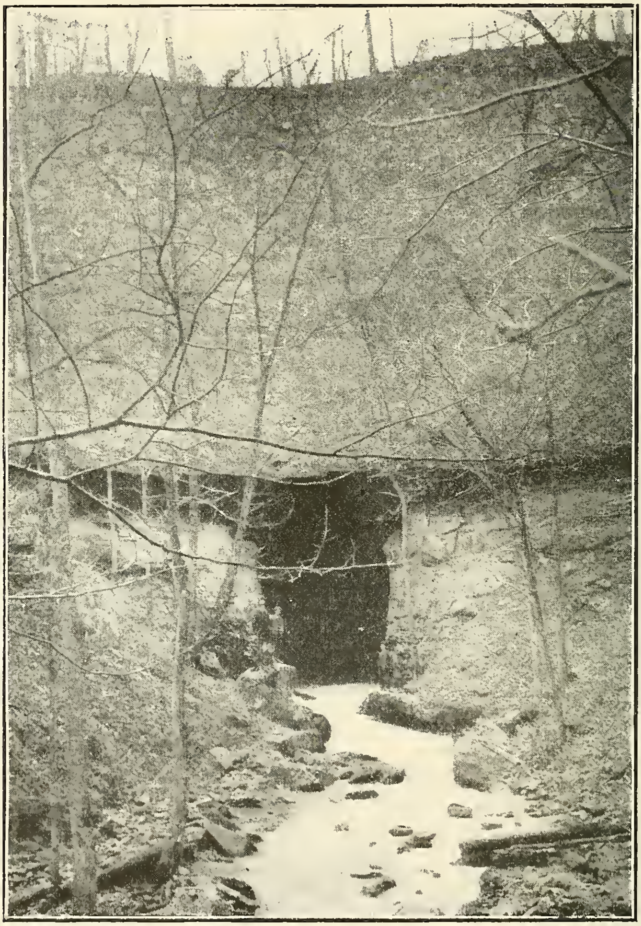

Fig. 11. Emergence of cave stream, mouth of Shawnee cave east of Mitchell, Indiana. The roof of the cave at its mouth is well supported. Just back of this there are two large rooms connecting with the main cave, leaving a large area of roof unsupported. It has faulted down about six inches. The completion of this collapse might, in time, leave a natural bridge at the present mouth of the cave. The valley is a typical collapse valley.

tendency is accentuated when the pirate is favored by the dip of the rocks, but frequently occurs in spite of the dip in cases where the dip is gentle. It is probably true that the only essential of such capture is that two streams lie one higher than the other in a region of soluble rocks sufficiently close to each other to permit the final entrance of some of the water of the one to the other. Examples of such piracy are by no means wanting in the Bloomington region.

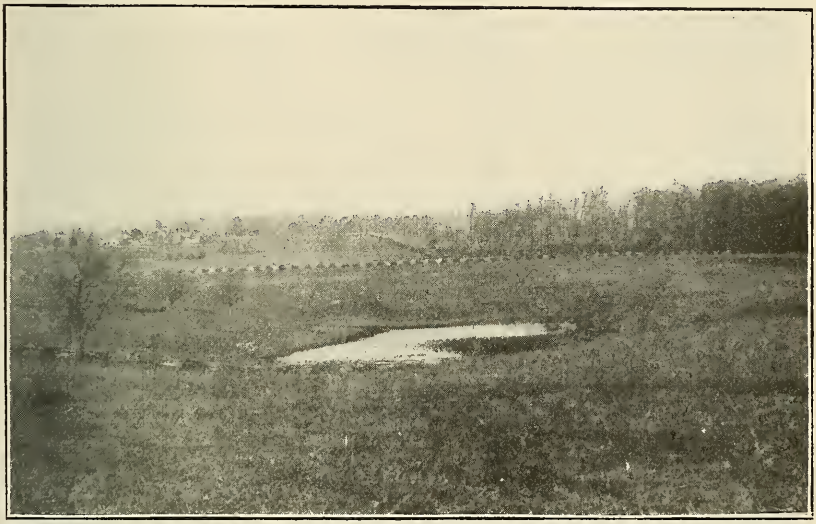

Fig. 12. A distant view of the Leonards Mill locality (Figs. 8 and 9), showing the form of the valley. The water from the Shirley Spring (Fig. 7) crosses the foreground.

In order to make these specific cases fully intelligible it is necessary to refer to some length to the physiographic history and conditions of the region. The well preserved plain west of Bloomington appears to be a very early Pleistocene peneplain. This plain extends at about the same altitude throughout the extent of the map, except that it is visibly beveled toward the major drainage lines, as will appear later. The peneplain is much dissected in the northeastern, southeastern, and western parts of the quadrangle. There are many monadnocks to be found along the old divides or near the headwaters of some of the minor streams, rising from a little over a hundred feet to two hundred feet or more above this old plain and reaching elevations of from a little under 900 feet to 1,000 feet A. T. The ones south of Kirksville are the best preserved and appear to be remnants of the very old Tertiary peneplain or, perhaps, base level. It seems probable that the whole region covered by the map and the higher, rougher parts of southern Indiana are a part of the Lexington plain of Campbell, reaching from the Cumberland Plateau westward to the Tennessee river,

Fig. 13. A monadnock southwest of Bloomington. It rises 115 feet above the surrounding plain. It is surrounded by sinks, especially on the north, west and south.

the Indiana portion being a spur extending northwest from the type region at Lexington. It will be noticed that the elevation of the old plain and monadnocks (catoctins) is materially lowered as the western edge of the map is approached. This is due to the surface dip into the West Fork of White river basin. A similar beveling will be noted on approaching Salt creek in the southeast corner of the map, and Beanblossom in the northeastern corner. Even in an extremely old peneplain this bevelling toward the main stream of the basin is the normal condition and should be expected to be found on a rejuvenated plain.

The physiographic history of the region may be briefly summarized as follows: When the Pleistocene peneplain had been developed the general level of the land was but slightly above the present level of the bottom lands of the larger streams. The streams flowed at about the level of the present larger streams, while the divides between them looked much as they do at present when viewed from the old peneplain west of Blooming-

Fig. 14. The Mitchell peneplain[9], about 4½ miles west of Bloomington. A part of the Indian Creek basin. The plain is here 160 feet above drainage level. Entire drainage subterranean.

ton. The valleys of even the small streams were wide and their bluffs indistinct. The landscape was wanting in angularity and was one characterized by gently flowing curves. All the streams seem to have meandered considerably upon their valley floors, the larger ones to a very great extent. Most of these features are well shown by the little streams in which

[9] The Sink-hole plain of Newsom. It is called the Mitchell peneplain since the country rock is the Mitchell limestone and it is typically developed at Mitchell, Ind., and southward.

the rapids have not yet reached the very headwaters and those which happen to be preserved just as they were upon the sink-hole plain.

The drainage was confined to the surface, since the streams and the water table were very near the general surface level. After this condition had been thoroughly established the whole region was uplifted without considerable tilting, to an elevation somewhat above that which it now possesses, an elevation amounting to upwards of 200 feet. Following this the

Fig. 15. View looking northwest from side of monadnock shown in Fig. 13. Closed sink in middle ground. Beyond is the plain of Indian Creek valley. Present drainage subterranean. The remnant of a monadnock (catoctin) interrupts the even sky line just at the right of the center of the background.

larger streams etched their channels to temporary base level, but soon afterward the region sank a little. As a result the streams flow at a level somewhat above the rock floors of their valleys. Other minor incidents occurred which have left their impress upon the region but which need not be discussed here. After the first elevation took place, rapids passed up the main streams cutting gorges in the valleys. As these rapids passed the mouths of the tributaries the latter were left out of adjustment with the master streams and reached them by rushing over high rapids and falls. Some of the larger tributaries reduced the lower parts of their courses with sufficient rapidity to prevent the development of extensive subterranean drainage beneath them, but this was not true of the smaller ones lying on the limestone plain. When the larger streams left the smaller ones hanging high in the air, subterranean drainage began in earnest. The

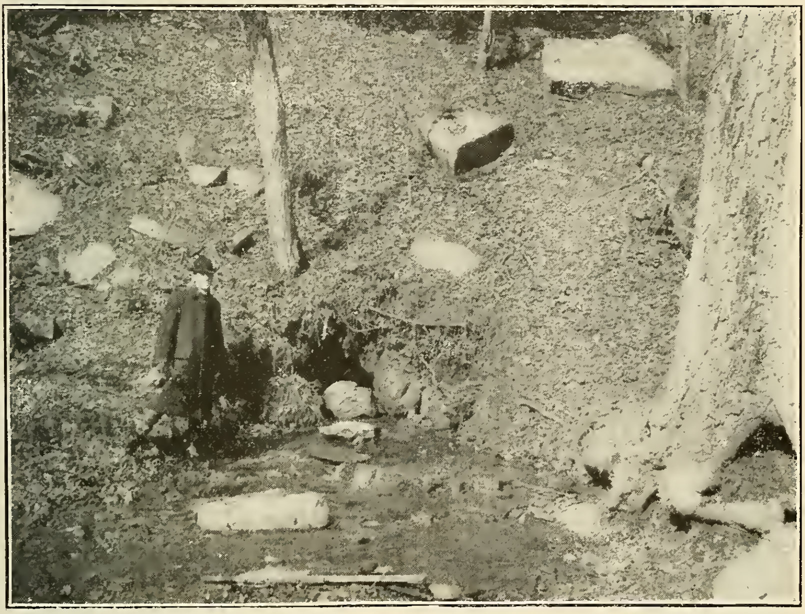

Fig. 16. Weimer Spring, Bloomington Waterworks.

rocks were saturated with ground-water and near the mouths of these streams was under an unbalanced static head of about a hundred feet. This water gradually flowed into the deeper valleys and was in turn replenished by more from above, and active underground drainage began and continued in the manner already indicated.

Fig. 17. View from side of monadnock, showing great terrace deposits on about the level of the Mitchell plain a mile south and 4 miles west of Elletsville. A somewhat interrupted monadnock divide forms the sky line in the distance.

Fig. 18. Gorge of the Cascade tributary to Rocky Branch north of Bloomington. This is a very small stream which has not reduced its whole valley to grade since the uplift. The valley profile is shown; the right side is clearest on account of the removal of the vegetation.

On turning to the Bloomington quadrangle some very peculiar drainage features will be seen. It will be noted that the headwaters of the western branches of Clear creek southwest of Bloomington and the eastern tributaries of Richland creek nearly west of Bloomington and north of Stan-

Fig. 19. View of the same valley, as shown in Fig. 18, looking in the same direction above the cascade, showing the old, wide valley with indistinct retreating sides. Were this valley developed in soluble limestones it is easy to see how the water might enter the ground above the cascade and appear as springs below it.

ford Station frequently lie in deep valleys with steep heads. On the plain between these two creeks is a region which is drained by great sinks opposite the heads of these streams. A little farther south Indian creek heads on this plain and continues a little west of south with gentle grade in its headwaters compared with the ones before mentioned. By following the valley at the head of Indian creek northward it will be discovered that the valley extends as far north as the race track west of the northern part of Bloomington, and that the water entering the large sinks just mentioned is really the water of the head of Indian creek. The same will be noted of the great sinks northeast and south of Blanche. The water, after entering these sinks, appears in the deeply incised heads of Clear creek and Richland creek instead of continuing down Indian creek. In other words, Richland creek and Clear creek have captured the waters of Indian creek by subterranean piracy.

This diversion of water was brought about by the location of the streams in question with respect to the rock structure of the region.[8] The strike of the rocks is nearly north and south. The lower rocks in the northeast and southeast part of the region are the soft, easily eroded "Knobstones." Salt creek, on account of its very large size, readily etched its lower course to grade and when the soft knobstone underneath the Mississippian limestone was reached it probably formed falls which rapidly retreated headward and permitted proportionally early deepening of many of its tributaries. Throughout the central part of the region the heavy, resistant, Mississippian limestones form the country rock, dipping westward, through which no drainage channels completely penetrated. The headwaters of Indian creek lie upon these rocks and nowhere do they cut through them. In a large part of its course the soft shales, sandstones and thin limestones of the Mississippian formations form the upland rocks. The result is that Indian creek with long and gentle grade could not compete with Clear creek, a branch of Salt creek, in deepening the channels of its headwaters. In the west part of the region the soft formations of the upper Mississippian and the basal soft sandstone and soft shales of the Coal Measures or Pennsylvanian rocks form the upland. The Mitchell limestone forms the beds and basal part of the bluffs of the streams in this part of the quadrangle. Richland creek for the most part lies in these soft formations and flows a short distance to the west fork of White river at Bloomfield, reaching about the same elevation as Indian creek flowing twice the distance to the east fork of White river north of Shoals, in Martin County. Richland creek being thus favored soon reduced the valleys of its headwaters below the level of Indian creek. This left the head of Indian creek 100 to 150 feet above the creeks on either side and its bed resting on soluble rocks. That is, Indian creek lay upon a table land of soluble rocks with lower streams on either side of it. The divide between Indian creek and Clear creek has been cut through and removed much of the way just southwest of Bloomington. Thus the headwaters of Richland creek northeast of Stanford Station are at a level of 680 to 700 feet above tide and were cut into the top of the Mitchell limestone which dips west from the Indian creek plain into Richland creek valley, while a west branch of Indian creek lay at an elevation of 800 feet but a half-mile or a little more to the eastward. The divide between the two is formed of the shales

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[8] See geologic map accompanying 28th Ann. Rep. Ind. Dept. Geol. Nat. Res. 1904

and sandstones of the Upper Mississippian. The result of this condition was that the water in the western branch of Indian creek, a mile or more south of Blanche, sank and reappeared in a great spring in the head of Blair Hollow a half-mile farther west. A similar thing occurred less than a mile northeast of Blanche and again about a mile and a half farther northeast. These sinks are the largest, or most extensive, on the quadrangle. As we approach the heart of the plain farther east the sinks become smaller and less conspicuous, the smaller ones not being shown upon the map.

On the eastern side of Indian creek valley we have large sinks. One of these is just north of the Water Works pond. Here the drainage entering the sink flows into the pond through Stone spring a few hundred yards farther south, entering the Clear creek valley, being diverted from Indian creek into which the surface drainage once flowed. Southeast of this there is a large sink east of the County Farm which receives the drainage of a large region to the north which normally belongs to Indian creek drainage but appears at the surface as a large spring in the north side of the branch of Clear creek valley in the N. W. ¼ of Sec. 24, nearly two miles south of the sink. The large sinks south and northwest of Leonards Schoolhouse have their outlet at Leonards Mill by the house in the head of the deep valley a half-mile south of the schoolhouse. Rags put in the upper sink are said to reappear at Leonards Mill.

From the foregoing it will be seen that the headwaters of Indian creek have been diverted into Richland creek and Clear creek by subterranean

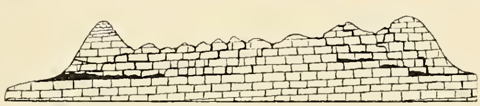


Fig. 20. A somewhat diagrammatic profile of a section across the valley of Indian creek into a tributary of Clear creek on the right and tributary of Richland creek on the left. The high points on either side of the figure are the old divides between the three drainage basins. It illustrates the manner in which Indian creek has been robbed of its waters southwest of Bloomington. The dip of the strata has favored Richland creek.

piracy. On the west this piracy is favored by the dip of the limestone and on the east it has taken place against the dip, which is very gentle. The sinks near the outlets of the underground streams are large, while those more remote and younger are smaller. The smallest are not represented on the map. There is another case of piracy in the sinks near Kirksville which is of the same type as that just described.

Other forms of piracy are probably much more common than the type described. That piracy occurs between adjacent subterranean streams seems very probable on account of the greatly varying levels occupied by them at different times and different parts of the same stream at the same time. This is facilitated by the fact that cave streams are below the level of the general water table and also because the falling of slabs from the roofs frequently clog the channels and temporarily fill the caves with water until further underground passages may be discovered and enlarged. It is impossible to cite specific cases at present because caves have not been explored with this object in view and because such cases will probably be difficult to recognize even under the most favorable circumstances.

Cases of subterranean self-capture, capture of one tributary by another, or by the main stream or the capture of the main stream by a tributary finding a short cut through a new channel are too common to be discussed at length here. A glance at Hovey's map of Mammoth cave is sufficient to suggest a most complex and interesting set of captures and changes of level for some one to work out.

RÉSUMÉ.

1. Extensive subterranean drainage is developed in interior regions only when they have been sufficiently elevated to allow rapid downward movement of the ground water and its easy access to drainage lines considerably below the general level of the land surface.

2. The conditions best facilitating subterranean drainage are regions well elevated with relatively impervious soluble rocks, well jointed and thinly bedded.

3. In regions of low elevation the sinks may be largely collapse sinks, and, in soft, porous rocks, the channels rather irregular.

4. The cycle of underground drainage may be stated as follows: It begins with surface drainage and in its youth develops subterranean drainage near the points of easy escape for the water. In its maturity there is the maximum of subterranean drainage and the lower parts of the caverns have begun to retreat by collapse while in the uppermost reaches of the stream the transformation from surface to subsurface drainage may still be in progress. Old age is shown by the more general condition of col-

lapse and the return to surface drainage. Briefly, it may be stated that the cycle is: surface drainage, partial subterranean drainage, and a return to surface drainage. The final state is peneplanation or base leveling.

5. In youth and maturity nearly all the sinks are solution sinks.

6. In old age many of the sinks are formed by collapse. Solution sinks may finally be transformed into sinks of collapse.

7. Surface streams resting on a plain of soluble rocks with streams at lower levels bordering them may have their waters diverted by subterranean capture.

8. Piracy probably takes place between subterranean streams and between parts of the same stream.

Bloomington, Indiana.

References to the "early pleistocene" peneplain in this paper should read "late tertiary (?)," since the cycle was interrupted at about the close of the tertiary or beginning of the pleistocene period.

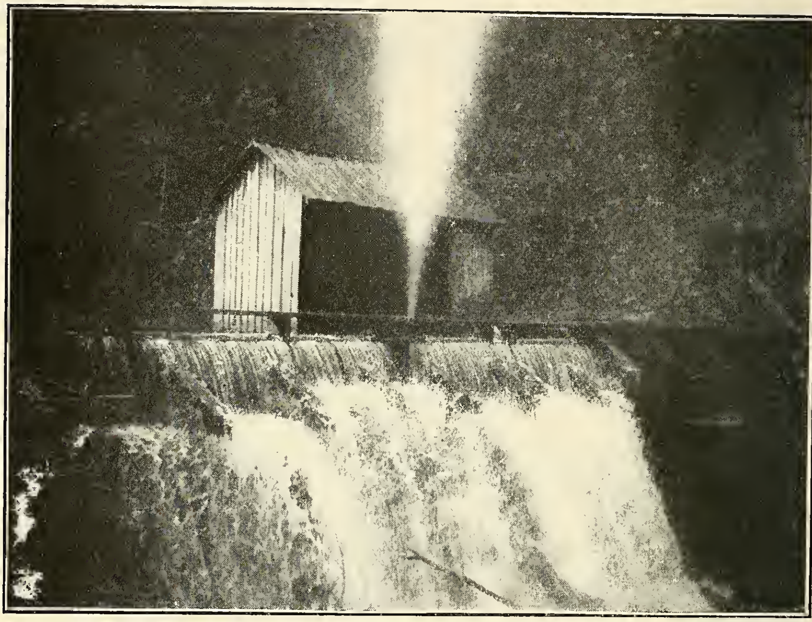


Fig. 21. Hamers Cave east of Mitchell, Ind. The water from this cave furnishes the supply for the two Lehigh cement plants at Mitchell. The picture shows the overflow from the dam. Water higher than usual.

Fig. 22. The "Gulf" of Lost river at Orangeville, Ind. Here the roof of the cave in which the river flowed has collapsed and the stream comes to the surface.

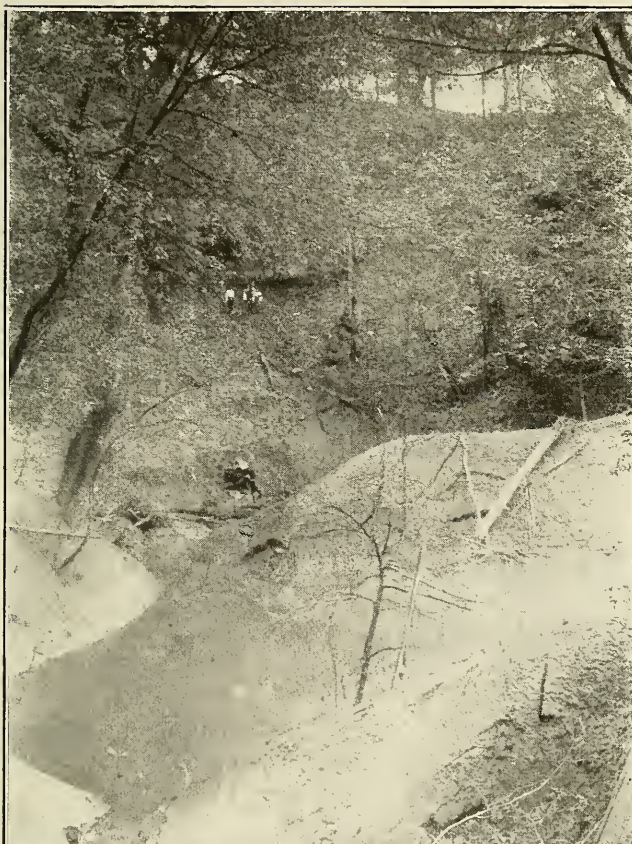


Fig. 23. A "Gulf" of Lost river above its outlet at Orangeville. The water rises to the surface at the right of the middleground of the picture and flows to the right and left, forming two streams, for a very short distance which sink and finally rejoin the subterranean channel. The little pond on the left side of the picture is one of the places where the water sinks. Just above the heads of the group in the middle background is a large cave, one of the abandoned subterranean channels of the river. The second, or present channel is considerably below the water shown in the foreground. Here a large area has collapsed blocking the lower channel and forcing the water to the surface, when it again finds new channels around or through the obstruction to its main channel again in which it continues.

Fig. 24. Abandoned channel of Lost river mentioned in explanation of previous figure.

Fig. 25. Phantom lake, near Toyah, Texas. A collapse sink where the subterranean stream is revealed. The roof, of Washita limestone, collapsed, filling the channel and forcing the stream to the surface—cave on the left—in a stream about six feet in diameter. It fills the depression formerly occupied by the roof with water and enters sinks in the immediate foreground to its channel below.

Fig. 26. A diagrammatic figure illustrating the origin of Phantom lake.

Fig. 27. Upper Dalton cave, part of Shawnee cave (Fig. 11) east of Mitchell, Ind. The location of cross caves and a sink at this point caused a collapse which brings the stream to the surface for several rods when it again continues in its subterranean channel.

Fig. 28. Lower Twin cave (part of Shawnee cave) looking north. Here the roof collapsed at a right-angled turn in its course where it appears to have been joined by another cave from the south. The location of a sink here caused a collapse similar to the preceding case. The water formerly flowed from the upper cave toward the east and then turned north into this opening—does at present during high water—but now occupies a cutoff between the two caves.

Fig. 29. Spring west of the large sinks north of Blanche. This is one of the sinks draining the western part of Indian creek valley.

Fig. 30. Old channel of Shirley spring, above present outlet, as shown in Fig. 7.

Fig. 31. Mouth of Wyandotte cave, a former location of an underground stream.

Fig. 32. Old opening to one of the large springs draining the Strongs cave sinks four miles west of Bloomington.

Figures 6, 7, 8, 10, 12, 13, 14, 17, 19, 21, 29, 30, 31, 32, from Professor Cuming's negatives.

The Shishi Gig.

By Albert B. Reagan.

Among the Quileute Indians of the Olympic Peninsula, Washington, the little tots from four to twelve years of age dance a dance called the Shishi gig. What significance there may be in the name is unknown. In this dance the participants get their bodies into a stooped, almost sitting position and then dance a vigorous forward dance, as is shown in the accompanying cut. At feasts and on special dance occasions, a prize is given to the child who can dance the longest in this semi-sitting position. Sides are taken and coaches cheer their respective aspirants on to get them to keep up the dancing. At these times the excitement runs high. The dance is an amusing sight

SHISHI GIG DANCE.

Notes on the Shaker Church of the Indians.

By Albert B. Reagan.

(Continued from page 71, Proceedings, Indiana Academy of Science, 1908.)

The Shaker Indians of the West Coast are now taking steps to incorporate the Shaker faith in an organized church. Judge Giles of Olympia, Washington, is now working up the articles of incorporation for the Indians. Soon they will have an organized church, a church by Indians and for Indians only. Temperance is their watchword; and healing the sick through prayer and laying on of hands and "shaking" over them is one of their tenets. The church about to be incorporated is copied in part from several denominations, besides imbibing the doctor—"tomanawis" beliefs of the old times including a part of the "tomanawis" ceremonies. The Episcopal church furnishes the idea of chanting prayers[1]. The Catholic church furnishes the custom of burning candles during the service and the old custom of making the sign of the cross and the bowing of the knee when "Jesus-Man" is mentioned. The shaking, body-jerking, the contortions, the muscle-quivering, the wried face, and the hypnotic influence are derived from the shamanistic customs of the old times. Hypnotism and shamanistic influence in general are the leading powers and are the things which actuate the Indian to perpetuate the religion.

In talking with a "shaker," he will always tell you he has felt the "power" and that is why he shakes so hard. "It is the power of God taking hold of him that makes him shake," he affirms. From the start it was my opinion that the "power" the shakers felt when shaking is hypnotism. To satisfy myself I went in among the actors several times. At once I could feel the "power." There was no mistake about it. I had often felt the same "power" at the old style medicine singings and dances from the Pueblo and Apache country to the land of the Norman Lion.

[1] The chanted "doxology" in the church language of the Shakers is:

"Kwax tsnahs mahah′ stee stah nah′ stee tah′ tsohn tohs pray′ kloh mahahs′ stee stah′."

Note.—The "stee" above is pronounced as though the first two letters were medium between "s" and "t," ranging between "st" and "ts" in pronunciation.

The accented words are much prolonged.

The power was undoubtedly hypnotism. The sensation produced was evidently that of hypnotic influence.

Once while I was attending one of these shaker meetings one of the actors was hypnotized. This was February 16, 1909. He had been standing with hands extended outward and upward for more than an hour while the shakers were dancing around him like the waves surging around a rock at sea in a stormy time. He was a novitiate at least for that night. He was trying to get the "power." He got it. He jumped up and down and stamped the floor in a circular movement, then for some minutes while his hands whirled, gyrated and his muscles quivered and jerked in a horrible manner. So hard did he stamp that he broke a hole through the floor. Soon he threw his hands up over his head and fell heavily to the floor. As he did so his muscles quivered as though he were in the dying stage. His flesh then became rigid. At this climax his pulse ran down to 57; five minutes later it was up to 60. Then as the spell was being broken twenty minutes later, it ran up to 76. The spell lasted forty minutes. Some of the Indians were scared, thinking the novitiate was dying. and rushed out of the hall. The performance over him was a complete hypnotic performance. The usual mode of removing hypnotic power was used. Hands were rubbed down his body and then the power thus gathered would be hurled to the four winds by a slapping, vigorous sliding of the hands across each other. When the "power" was removed so that consciousness was restored, the novitiate entered the dance vigorously again.

Effect of Shakerism upon the actors: The terrible shaking that has been mentioned here and in the previous article is bound to undermine the health of any person who will participate in it. Besides, the heating up of one's self as is done in the shaker halls and then the going out of doors immediately afterwards, tend to the giving of colds to the participants, especially in the winter months. This undoubtedly, will lead to pneumonia, consumption and death to many. Again, the horrid wrying and contorting of the faces will cause them to be wrinkled prematurely. The muscle-quivering and the hypnotic influence is bound, also, to have a damaging effect upon the nerves and mind of the actor; this dance is kept up all day every Sunday and from three to four hours every Thursday. Furthermore, in the doctoring of the sick the shakers are fanatical in the belief that shaking over the patient will cure it. "All shake—no medicine" has killed many an Indian and will in time decimate the tribes holding, such beliefs.

The Wreck of the "Suthern."

By Albert B. Reagan.

About 1850 a revenue cutter (?), the "Suthern" was damaged at sea in a storm; and, to save the crew, the captain ran the vessel ashore in the old mouth of the Quillayute River near what is now the Indian village

of LaPush, Washington. Immediately on grounding, the vessel was taken possession of by the Quileute (Quillayute) Indians. The savages boarded her and emptied her supply cargo into the sea. The dried fruits and the flour they knew not how to use as they had never seen such things before. So they emptied the fruit overboard to get the pretty boxes. They also poured the flour into the surging surf that they might get the sacks to make into clothes. The money of the ship also fell into their hands. It was gold. They had never seen gold before. They knew not its value or purpose. So they rolled the double eagles around on the beach and used them as disks in their gambling games. They also made prisoners of the crew; and for a time all were ill treated very much. Finally, Chief Howeattle, who was up the river at the time of the capture, compelled the Indians to release them. By this time the storm had pounded the vessel beyond repair. At that time there was no communication from the Olympic peninsula with the outside world. So Chief Howeattle had houses built for his now guests. He also furnished the houses as best he could with his meager means. He also gave the single men of the crew Indian wives that they might be more contented in their forced home; two of his sisters married members of the crew. For a considerable time the strangers were compelled to stay there. At last a note was got out to civilization by an Indian messenger; and, finally, they were rescued by another government boat and taken to their respective homes, the men leaving their Indian wives behind with their own people.

Time passed, and years. Finally, another government vessel hove in sight. It anchored in the bay and from it many presents "from the Father in Washington" and the white people who had been stranded there were brought ashore and given to the good chief and relatives. The government also built Chief Howeattle a house and put a brick, fireplace in it for his saving the people of this vessel. They also furnished the house for him. But Mr. Howeattle was not permitted to enjoy his present long. A fire burned it to the ground. He, however, had the satisfaction of knowing that he had the good will of the white people and that he had done right.

The wreck of this old vessel can still be seen at LaPush. In summer it is covered with sea wash; but in winter the waves carry the sand far out to sea. Then, there exposed to view are the "irons" to remind one of the days of the wreck in that long ago and the change that has come over the country and the aborigines since that time.

Effect of Ice in Lake Upon the Shore Line.

By Albert B. Reagan.

On coming to northern Minnesota last year, I visited several islands in Pelican Lake near Orr, in St. Louis County. The country in that region is very stony, mostly boulders of glacial origin. Around the borders of several of the islands, especially the low islands, there was a ridge of cobble stones and boulders, sometimes almost assuming the form of a stone fence. It struck my curiosity. It was spring, however, before I had solved the mystery. At the breaking up of the ice in the lake, a strong southwest wind drove the ice upon the islands on the wind-exposed sides to a height of over twelve feet in one case, a literal glacier being shoved inland. The ice being thus shoved forward and piled up on the land, shoved the loose rock of the shallow lake next the island inland so that the "moraine" thus formed was the stone wall I had noticed. It might also be added that some of the scratchings on shore rocks of lakes in this northern region may be due to the same local action.

The Boise Forte Indian Reservation in Minnesota.

By Albert B. Reagan.

The Bois(e) Fort(e) Chippewa Indians live in northern Minnesota on a reservation of the same name surrounding the beautiful Nett Lake. The reservation covers one whole township and eight fractional townships. Its eastern part is in St. Louis County, the bulk of it in Koochiching County. It contains a total of 103,862.73 acres, exclusive of the area of the lake. Of this area, 55,646.43 acres are allotted to 693 Indians, 48,216.30 acres remain unallotted, and 434.64 is reserved for agency and school purposes. Of the 48,216.30 acres unallotted much of it has been reserved by the Government as pine lands and from time to time the timber on parts of the said lands has been sold under sealed bids, the closing out sale occurring September 15, this year. In all the timber on 9,533.70 acres has been sold, 3,233.77 being sold September 15, 6,299.93 having been sold previously. The other unallotted lands will be subject to settlement as homestead lands in the near future. There will also be something like 30,000 acres of Inherited Indian lands to be sold within the next two years.

Nett Lake is in the east central part of the reservation. It is more than half a township in area. It is in the shape of a giant lobster's hand with the claws pointing eastward, the large claw being the north digit. The lake is shallow and has a mud buttom. It is a rice field and a duck pond combined. In summer, it looks like a vast wheat field. In the fall it swarms with ducks and consequently is a sporting center for the hunters of all this northern country.

The lands included in the reservation are well timbered. The principal species represented are white and Norway pine, spruce, cedar, elm, cottonwood, oak, birch, and poplar. The latter two are the most abundant and will be of value some day as pulp wood.

The land of the reservation is very variable in condition of soil and possible fertility. One-half of it is swamp and is known to the Indians as "Muskeg" lands. Over this area there is a stratum of peat from six inches to five feet in thickness. When once drained this will be the best land in the country. The non-swamp eastern part of the reservation is composed of rock-ridges flanked with lower land. These lower stretches are clay flats covered with black loam. On them grow birch and poplar forests; and when cleared they will make fine farms of the dairy type. Roots and grass do well on such lands. The ridge lands are the pine lands and will not be of much value, except for building sites and orchard locations.

The western part of the reservation that is not covered with "muskeg" swamp is a sand region. On it grew much pine in the old times; but when cleared it will be practically worthless, as is some pine lands east of the south lobe of the lake.

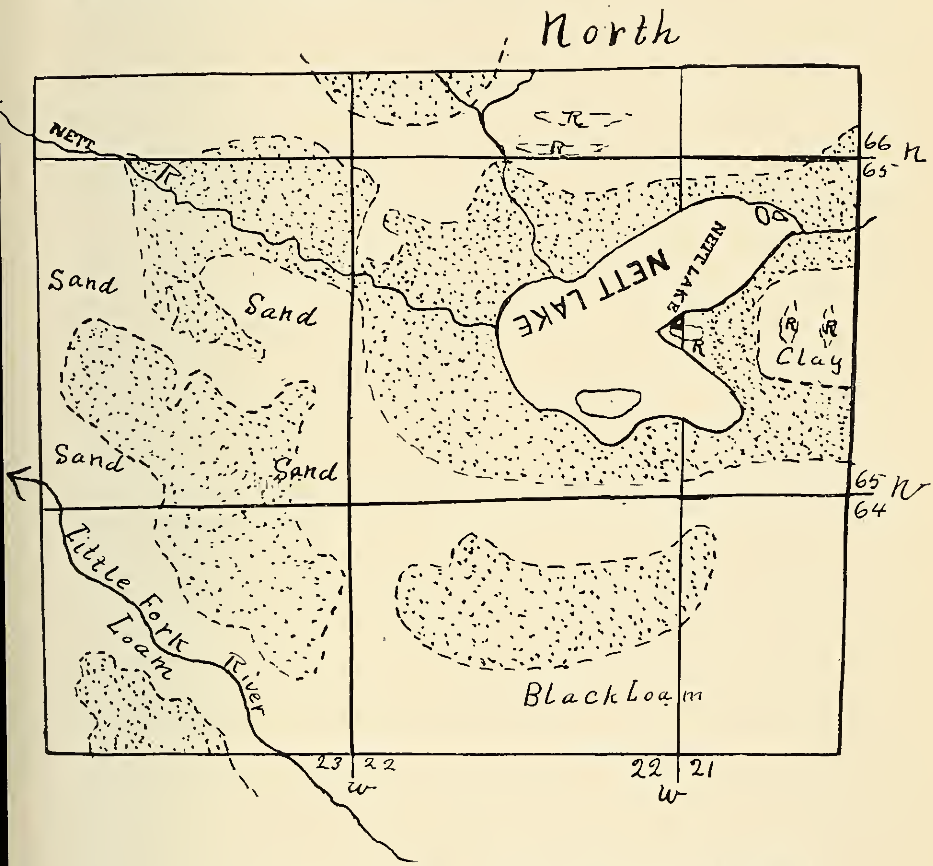
The region about Little Fork River is in the southwestern part of the reservation. It will make good farm land when cleared. Some open areas are fine meadows now.

The surface material, except that on the ridges, was left on the retreat of the glaciers. Its depth varies from nothing on the ridges to 200 feet in the pre-glacial intervalley spaces. The irregular dumping of this material and the partial filling of ancient valleys has produced the lakes of the country. In composition, this material varies very much. In the eastern part of the reservation it is composed principally of ground moraine material—a blue clay filled with boulders. Some of these are found to be of local origin; others to have been transported from a region far to the north. At other places on the reservation, the formation appears to be practically pure sand. On the rock ridges the glacial debris is entirely wanting, but instead the exposed rocks show the glacial scratchings.

The climate is very changeable in this part, ranging from 102 degrees above zero in summer to 60 degrees below in winter. The average summer is too cool for corn, and wheat has never been tried. Oats does fairly well.

The Indians have been allotted nearly twenty years; yet not one of them has ever made any effort to improve his allotment. As yet there is little inducement for them to improve them. There is no market where they could sell their produce. Furthermore it would cost $100 per acre to clear the land, which is rather a big undertaking for a poverty-stricken Indian. In addition, there is rice growing in the lake and plenty of game in the woods and water fowl among the rice in the lake. Why should he labor to clear his land?

Below is a surface map of the reservation, showing the formations as they occur. (The original country rock is not shown.)



MAP OF THE BOIS FORT INDIAN RESERVATION IN MINNESOTA.

The dotted areas are swamp, or "Muskeg," to use the Indian term. "R" stands for rock ridge. The other kinds of land are designated on the map. Any one examining this map could not blame the Indians for petitioning the Honorable Commissioner to have lien lands allotted to them for their swampy allotments.

Conservation Problems in Indiana.

By Frederick J. Breeze.

When the organized movement toward the conservation of natural resources began with the White House Conference of Governors in 1908, very little attention was given it. But wide publicity was given to the new undertaking, and because of the people's faith in the integrity of purpose of its leaders, Roosevelt and Pinchot, the movement met with very general favor and enthusiasm. We had already seen the essential principles of conservation successfully applied in the management of the Federal forests and irrigation enterprises. Not only did the conservation movement stand out against the useless destruction and waste of natural resources, but also against the century-old policy of the government almost giving away its great resources of forests, water power, and minerals to corporations which were becoming gigantic monopolies. At once, conservation became a scientific and economic problem. The rapid reforms that followed the agitation for conservation struck terror to the monopolies and individuals who were getting control of our great national possessions; and conservation has been compelled to fight against the crafty, powerful and insolent onslaught of certain vested interests. The history of the past year is primarily a story of this struggle. The fight is by no means over; but the National Conservation movement has gained some very decisive victories, and today conservation enjoys a very marked degree of popularity. Already the close observer can see the tendency of certain classes of men to eagerly support the conservation policies in order to secure public favor for themselves. Other well meaning people are insisting on becoming leaders of the movement, whose enthusiasm surpasses everything except their deplorable ignorance of conservation itself.

In view of the recent beginnings of conservation activity in our own State, it may be well to briefly recall to your minds some of the conservation problems of Indiana.

Two natural resources are almost entirely depleted, our great virgin forests and natural gas. While the removal of our forests was necessary for agriculture and the demand for lumber, yet it must be admitted that deforestation has taken place to a greater extent than the actual needs of agriculture called for. The criminal waste of natural gas is quite recent history; and the industrial consequences of its failure are painfully evident in the manufacturing cities of the gas belt.

Our natural gas and primeval forests belong to the past and are things therefore beyond the help of any conservation. But we have a great wealth of natural resources which need our most careful attention.

Present Forests.—Our existing forests are made up of limited areas of primeval forest, and second-growth timber of inferior quality on our stream bluffs and other waste lands, and in the farmers' wood lots. In the matter of afforestation there must be an improvement in the character of the growing trees in the wood lots, which can only be brought about by scientific forestal methods. Each farmer must be as competent in tree growing as in corn and wheat growing. In southern Indiana and along the streams of northern and central Indiana we have a large combined area of land too steep for successful field culture; and for the sake of soil protection, and for future lumber supply, these tracts should be kept in perpetual forests. In this matter of forests upon non-agricultural lands, there should first be a careful survey of such lands in order to form an accurate estimate of the total area, and to determine what species of trees are best adapted to make a rapid growth of valuable timber. It seems quite safe to say that the present woodland areas are of sufficient acreage to meet all the needs for lumber within our own State, if the quantity and quality of timber grown will be what it should be.

Soil Fertility.—The most valuable natural resource of our State is its soil, and the maintenance of its fertility is of paramount importance. The loss in fertility due to poor agricultural methods is beginning to be keenly felt. The loss due to soil erosion in southern Indiana was ably presented in the Presidential address of two years ago.

Sewage Pollution.—No conservation program can ignore the problem of keeping the state waters pure. Our streams must be brought back to their original purity. As our population becomes more dense, the need of a pure water supply becomes greater, and it becomes imperative that we stop polluting our streams with sewage. The turning of sewage and factory wastes into our streams is not only vicious from the standpoint of sanitation and aesthetics, but the carrying of sewage to the sea is a waste of certain elements of soil fertility which should go back to the land instead of being lost in the ocean.

Coal Deposits and Other Mineral Wealth.—In the matter of coal mining there must be a steady insistence that wasteful methods of coal mining must stop. In the mining of the best veins of coal, the layers of lesser value are left in such a condition that their removal in the future will be almost impossible. The securing of large dividends in the mining industry must not be at too serious a sacrifice of the future supply of coal. There also can be an enormous saving effected in the consumption of coal for heat and power by the general adoption of appliances for complete combustion.

Water Power.—In this State, water power is practically an undeveloped resource which is yet the property of the whole commonwealth and from the very nature of flowing water is not subject to private ownership. It is an outrage that our State laws enable individuals or corporations to get the control and profit of the available power of a stream simply by purchasing a power site and building a dam, without giving to the State one cent of revenue. There can be no more important thing in the conservation program than to insist on the passage of laws that will clearly establish the principle that water power belongs to the State, and that will provide for the leasing of water power rights for a definite term of years at a rental that will be fair to the power company and to the people of the State.

Conservation of Public Health.—The campaign for public health has been carried on so efficiently by our State Board of Health under the leadership of Dr. J. N. Hurty that it is not necessary to do more than suggest that this phase of conservation must always be of the very greatest importance.

Scenic Beauty.—Another phase of conservation should be the preserving of the natural beauty of the State. More and more will our State become crowded with artificial features; and the desire for beautiful natural features will be correspondingly greater. We must insist that the beauty of streams and hillside, trees and flowers, and songs of birds are worth while, and that the future development of our resources shall not destroy these things. I hope that the State Federation of Clubs will make this subject its chief conservation activity.

Conservation Organizations.—Within the last few months we have seen the formation of organizations to do special work along lines of conservation. The value of these bodies will depend very largely upon the ability and fitness of the leading members to be leaders in conservation. Any organization that expects to obtain and hold the support of the people of the State must have as its leaders the men who are engaged in scientific work in soils, waters, forests, public health, and kindred subjects. Any association to conserve or develop a natural resource must be conspicuous in having as its leaders men who have first-hand knowledge of the natural resources involved; and not be conspicuous by the absence of such men. It must always be kept in mind that the most important conservation work must be done by the farmers, and that no organization which is promoted by a self appointed leader can win the attention or co-operation of the workers in whose hands must rest the burden of real and enduring conservation.

State Agencies.—Let us not forget that we have permanent governmental departments whose work is along important conservation lines, such as Geology and Natural Resources, State Board of Forestry, State Board of Health, etc. We should see to it that the people have a chance to become better acquainted with the splendid work of these scientific departments. Their usefulness is limited only by the amount of money appropriated for their use. We can do no better work than to insist that these conservational agencies of long-tried efficiency be given more money in order that they may render still better service to the State.

Crustacea of Winona Lake.[1]

By John L. House.

Two hydrographic maps of Winona Lake with descriptions have been published; one by Large (Proc. Ind. Acad. Sci., 1901) and another by Norris (Proc. Ind. Acad. Sci., 1901). The lake is situated in Kosciusko County, Indiana, about one mile southeast of the city of Warsaw. It is irregular in outline and has an average length of about one and one-eighth miles north and south and an average width of nearly three-fourths of a mile east and west with a large bay extending westward from the north end. There is comparatively only a small amount of shallow water in the lake as the bottom slopes off rapidly from the shores and reaches a maximum depth of eighty-one feet.

The fresh water crustacea are well represented in this lake both in variety of forms and in number of individuals. It is not probable that this list enumerates all the species to be found here.

The material for this report was collected during the months of July and August of 1908 and 1909 in connection with the work of the Indiana University Biological Station. Many thanks are due to Dr. C. H. Eigenmann, Director of the Station, for the many courtesies and suggestions received.

The Entomostraca were taken at about all hours of the day and night by means of the tow net, dip net and by pumping. The day catches showed very few forms near the surface even on cloudy days, but they were abundant near the surface from one to two hours after sunset until about sunrise. The nauplius forms were not numerous at the first of July, but became more abundant as the season advanced.

[1] Contributions from the Zoölogical Laboratory of Indiana University, No. 118.

The following list includes the species that have been identified:

CRUSTACEA.

Sub-Class Phyllopoda.

Order Cladocera.

Sididæ.

Sida crystallina Mueller.

Pseudo-sida tridenta Herrick

Daphnella excisa Sars.

Daphnidæ.

Ceriodaphnia reticulata Herrick.

Ceriodaphnia scitula Herrick.

Ceriodaphnia lacustris Birge.

Scapholeberis mucronata Mueller.

Simocephalus vetulus Mueller.

Simocephalus serrulatus Koch.

Daphnia minnehaha Forbes.

Daphnia retrocurva Forbes.

Daphnia pulex DeGreer.

Daphnia hyalina Leydig.

Bosminidæ.

Bosmina cornuta Jurine.

Bosmina longirostris O. F. Müller

Bosmina striata Herrick.

Lyncodaphnidæ.

Sub-family Eurycercinæ.

Eurycercus lammellatus O. F. Müller

Sub-family Lynceinæ.

Acroperus harpæ Baird.

Alona quadrangularis Müller.

Alona costata Sars.

Pleuroxus procurvus Birge

Procurvus denticulatus.

Sub-Class Copepoda.

Order Eucopepoda.

Calanidæ.

Osphranticum labronectum Forbes

Diaptomus birgei Marsh.

Diaptomus oregonensis Lilljeborg

Diaptomus pallidus Herrick.

Episcura lacustris Forbes.

Cyclopidæ.

Cyclops brevispinosis Herrick.

Cyclops leuckarti Koch.

Cyclops pulchellus Koch.

Cyclops signatus Koch.

Cyclops modestus Herrick.

Cyclops capilliferus Forbes.

Cyclops insignis Claus.

Cyclops serrulatus Fischer.

Cyclops fluviatilis Herrick.

Cyclops fimbriatus Fischer.

Cyclops prasinus Fischer.

Order Siphonostomata.

Lernæopidæ.

Specimen found on gills of the Black Bass (Micropterus salmoides), species undetermined.

Sub-Class Ostracoda.

Cyprididæ.

Cypridopsis vidua O. F. Müller.

Sub-Class Malacostraca.

Order, Decapoda.

Astacinæ.

Cambarus diogenes Girard.

Cambarus propinquus Girard.

Cambarus immunis Hagen.

Order, Amphipoda.

Orchestidæ.

Hyalella knickerbockeri Bate.

Order, Isopoda.

Oniscidæ.

Porcellio rathkei Brandt.

Asellidæ.

Asellus tomalensis Harford.

The economic importance of the smaller crustacea is well known They form one of the most important food supply links between the lower plants and animals on the one side and the higher animals on the other. A small minnow about one inch long was kept for some time and fed on Amphipoda (Hyalella knickerbockeri). A small darter hatched from the egg and cared for by Mr. W. I. Lower was fed on Entomostraca, principally Ostracoda, until it was eighty-seven days old and was about three-eighths of an inch long.

As parasites the small crustacea frequently cause great mortality among fishes, but so far only one parasitic form has been found in Winona Lake and that in extremely small numbers on the gills of the Black Bass (Micropterus salmoides). Examination of other fish and of the clams in the lake failed to reveal other parasitic crustacea.

Three species of crayfish were found. *Cambarus propinquus* was abundant in the streams flowing into the lake and also in the outlet, but was extremely scarce in the lake. Cambarus diogenes and Cambarus immunis were found only in burrows along the shore and along the edge of the streams and in the adjacent low ground. The burrows are from two to three feet deep and contain six to eight inches of water at the bottom. Where the soil is homogeneous they extend obliquely downward in almost a direct course, but in the presence of stones and other obstructions they wind about sometimes to a considerable extent. In digging the holes the crayfish work head downward and bring the earth up between the chelæ and the first pair of walking feet and deposit it by the aid of the second pair of walking feet. Attempts were made to get the burrowers out of their holes by pouring strong salt solution and also formalin into them. But the crayfish would die before they would come to the surface. Traps at the surface were also resorted to without success and the only practical method of obtaining them was by means of a ditching spade which required no small amount of labor.

While the crayfish were always found in shallow water, under and among stones and sticks or in burrows, it was found that they could live in deeper water. One pair each of C. propinquus and C. diogenes were placed in a wire cage in six feet of water at the mouth of Cherry creek July 21, 1908, and were fed from time to time. They were alive and in good condition when taken out August 24, 1908. It was found, however, that they would not live in extreme depths. One pair each of C. propinquus and C. diogenes were placed in a wire cage in forty-five feet of water and were in good condition two days later. But when placed in sixty-five feet of water they perished in less than twenty-four hours.

A Method by Which Cover Glasses May be Used on Golgi Slides.

By D. W. Dennis.

It has been well known for many years that Golgi slides of the brain, spinal cord, etc., will go bad if a cover glass is put on them.

Several years ago serial sections of a mouse's brain were prepared by this method in the Earlham laboratory by Mr. Levi Peacock. Three years ago I concluded to sacrifice one of these slides in order to get a medium power photograph of some Purkinje cells, so the balsam was warmed and the cover glasses put on. Last summer the slides were still in excellent condition. I accordingly had cover glasses put on all the slides last winter and they are still all in good condition. How long a time must elapse after a slide is made before it will bear a cover glass without damage we shall now work out.

A Tropical Reptile near Richmond, Indiana.

By D. W. Dennis.

A large reptile, Iguana tuberculata, was taken three miles from Richmond, Ind., in October. The man who shot it, a negro, undertook to carry it home by the tail and broke off what he estimates was a foot and a half of the end of its tail. What remains is about three and a half feet long. As this is a tropic species, we suppose that it must have escaped from some traveling show or from some private collection. No clue has been found. The skin will be prepared for the Earlham museum by Ward of Rochester.

A New Bed of Trilobites.

By Andrew J. Bigney.

It is conceded by those who have studied the rocks of Dearborn County that there are few sections in the country that are richer in invertebrate fossils. The Richmond formation is the outcropping stratum. In many places the streams have cut into the underlying Lorraine. During the past ten years the erosive action of the streams has been much greater than during any previous period of equal length of time. This is largely due to the removal of the forests from the hills and the cultivation of these lands for various crops. An examination of almost any stream shows the deep channels revealing new formations and rich beds of fossils, with interstratified clays.

It was in such a place as this, one mile northeast of Moores Hill, that I discovered a small bed of Trilobites of the species Calymene (species?). The bed does not measure more than three feet by four. The rocks are about three inches in thickness. It is of compact limestone, composed entirely of the trilobites, most of which have been partly dissolved and recrystallized. Enough of the trilobites remain to enable one to recognize them. Nowhere in this section have there been so many trilobites found in any one place. Usually they are very scattering. Twenty-five years ago many specimens were found in various parts of the county, but I have never learned of so rich a find as this. In the same stream and not far away there are a few specimens to be found. This must have been an isolated portion of the ancient sea, especially favorable for the growth and accumulation of the trilobites.

The Occurrence of Conglomerate and Sandstone of Post-glacial Origin in Jefferson County, Indiana.

By Glenn Culbertson.

The city of Madison, Jefferson County, Indiana, has been built on a great sand and gravel bar. This bar is approximately three miles long, from a quarter to a half mile wide, and of varying depth up to sixty or eighty feet. It is composed quite largely of sand, gravel and pebbles of glacial origin, water worn and deposited by the Ohio river. The bar deposit was very probably formed contemporaneously with the "second bottoms" or the first terrace of the Ohio river, and during the time of flooded waters as the later glaciers were melting.

Crooked creek, a stream some eight or ten miles long, which in glacial or preglacial times emptied into the Ohio near what is now the upper part of the city was deflected by these deposits, and now flows approximately parallel to the Ohio river for some three miles, emptying into the larger stream at a distance below the pumping station of the Southeastern Hospital for the Insane.

It is along the banks and on the slope to the south of Crooked creek

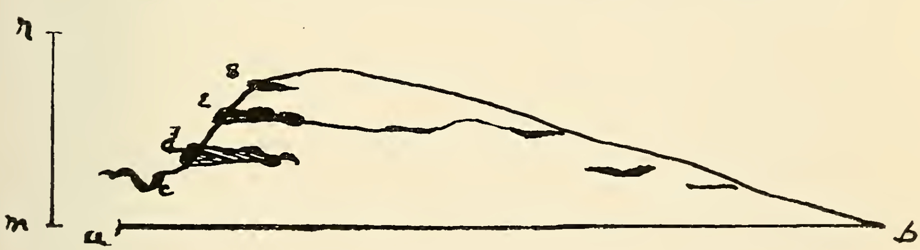


Fig. 1.

Ideal cross section of gravel bars and conglomerate deposits. Width of bar a b equals one-fourth mile; height m n equals 60 feet.

(c) Bed of Crooked creek.

(d) Position of thickest conglomerate and sandstone deposits, irregularly placed.

(e) and (s) Other irregularly placed deposits of indurated rocks.

(a b) Low water mark Ohio river.

that the more important sandstone, gritstone and conglomerate formations may be seen. Their outcroppings are especially noticeable along the slope south of Crooked creek, and between the large fill of the Pennsylvania railroad and the bridge over Crooked creek on the Hanover road.

So far as determined from sections seen in a few short valleys, on the creek banks, and in a large gravel pit, the consolidated sands and gravel are more abundant on the side of the bar farthest from the river, and on the slope near the creek. Here the conglomerates and sandstones are in several irregularly placed layers which vary in thickness from a few inches up to six or more feet. The formations are not of uniform thickness, and grow thinner the farther they are from the creek and the exposed slope. The accompanying ideal cross section of the portion of the bar from Crooked creek on the north to the Ohio river on the south in the locality above mentioned shows the relative position and general character of the formations.

The cementing material, so far as tested, was found to be calcareous. Much of the stone is quite compact and firm, but a part of it is more or less friable. In general the upper portion of any layer is the more indurated. In a few limited areas the upper surface of the conglomerate appears to be cemented by material of stalagmitic character. By far the greater part of the formations, however, gives no evidence of the existence of cementing material of that nature or origin.

The formation is peculiar from the fact that the cementation and consolidation took place above the water and in the absence of any considerable pressure. In the opinion of the writer the cementation of the sands and gravels was the result of capillary action. The waters of Crooked creek, which flow throughout their course over limestone and calcareous shales become at times strongly impregnated with calcium carbonate. This was preëminently the case when the stream was low at the time of a drouth. On the arrival of the waters at the place of the present conglomerate formations, the slope of the stream and the character of the bed were such that the movement of the water was very slow. Hence much of the water with its content of calcareous material passed into the sandy and gravelly banks, and then was drawn up by means of capillary action through the firmer close-textured beds. On approaching the surface of the beds the water evaporated and left a residue of calcium carbonate. This residue, on being deposited between the grains of sand, the particles of gravel and the pebbles cemented them together into the solid rock.

The character of the beds of material underlying the consolidated portions is such that capillary action was not only possible but highly probable. The greater abundance and the greater thickness of the indurated beds on the side of the gravel bar nearest the creek indicates that its waters were largely responsible for the presence of the cementing materials.

In explanation of the formation in places of material resembling stalagmite, it is probable that surface waters flowing over or through the more or less consolidated rock redissolved a part of the cementing material, and when such waters reached the surface of the soil or rock at a lower level they were evaporated and the calcium carbonate was again deposited in the form mentioned.

A Physiographic Survey of the Terre Haute Area—Report of Progress.

By Charles R. Dryer.

The physiographic survey of the Terre Haute area reported last year has been continued during the past season and extended across the Wabash valley to the top of the east bluffs. A strip six miles wide, north and south, has been completed, and we have been brought face to face with the problem of the sand and gravel terrace, three miles and more in width, 50 feet above the river and more than 100 feet deep, which extends along the east side of the valley a distance of 30 miles. Within the area surveyed its generally level surface is traversed by several irregular north-south ridges, which rise to a nearly uniform height of 510 feet A. T. These are interpreted as being bars laid down by a loaded and probably braided stream. In some places these bars are capped by subsequent eolian deposits. The materials of the terrace are everywhere fairly well assorted and stratified, with frequent cross bedding, where the strata dip down stream and suggest local delta formation. The strata in vertical section often display a great variety and testify to frequent local changes in the velocity of the depositing stream. Boulders up to two or three feet in diameter are common and are attributed to the melting of floating ice.

The terrace heads 12 miles north of Terre Haute in Parke Co., where the Shelbyville moraine of the Wisconsin ice sheet crossed the Wabash valley. At this point the problem is complicated by the extension of the terrace up the valley of Raccoon creek to the northeast where it is more than a mile wide. The final solution requires the extension of the survey to the Shelbyville moraine and up the Raccoon valley to a distance not yet determined. This work has been begun, but is not yet completed. So far as studied, the terrace appears to be an outwash plain, or valley train, laid down by a constantly overloaded stream, or streams, which issued from the margin of the Wisconsin ice sheet. Whether this is the true interpretation, whether the train originally occupied the whole width of the valley, and, if so, what were the agencies and conditions of its removal from the west side of the valley, are problems which we hope to attack in the future.

The margin of the east bluff is capped by a broad ridge of sand, standing 20 to 30 feet above the general level of the till plain to the east of it, and exhibiting in many localities characteristic eolian topography. The surface sands are underlaid by loess, and the whole deposit is interpreted as having been blewn up by westerly winds from the valley below.

The small streams from the east which break through the bluff have wide flat-floored valleys opening upon the terrace with accordant grades. In their natural state, none of them ever extended their channels across the terrace to the river. Their waters, ponded in depressions between the bars, sunk into the sand or evaporated. The depressions are generally puddled with a thin coat of lacustrine silt.

The Work Done by Normal Brook in Thirteen Years.

By Charles R. Dryer and Melvin K. Davis.

A small stream which enters the Wabash valley three miles east of Terre Haute attracted the attention of the senior author of this paper many years ago by its remarkable meanders. Within a length of 1,000 feet it presents most of the phenomena characteristic of the lower Mississippi, and it has been visited so often by geography and geology classes from the Normal school that it has acquired the name of Normal brook.

The stream rises by two principal forks which drain about a square mile of Illinoian glacial clay plain, cuts through the east bluff of the Wabash valley and is lost upon the great gravel terrace below, by percolation and evaporation. Along the edge of the bluff the clay overlaid by a belt of sand dunes about half a mile wide, and the most interesting part of the stream, is that where it passes through the dune belt. A hasty survey of this part of the valley was made in 1897 and a map of it was published in the Inland Educator for June, 1898. During the past season (1910) a second and more careful survey has been made and a comparison of the two maps shows the changes which have taken place in thirteen years. (See Figs. 1 and 2.)

The part of the valley shown measures along the median line 1,150 feet, while the stream, by its meanders measures 1,960 feet, an excess of 68 per cent. In the upper 650 feet of the valley the length of the stream is 1,360 feet, an excess of 109 per cent. The valley floor, 100 to 200 feet wide, is flat flood plain bounded by bluffs 25 to 40 feet high. The material exposed on the floor is wholly alluvial, mostly sand with occasional bars of fine gravel and beds of tough, blue clay. In the valley floor the stream has cut a channel 20-70 feet wide and three to six feet deep. The stream is perennial and in ordinary stages is a thread of clear water four or five feet wide and six inches to a foot deep, which is much more crooked than the channel. In times of flood it fills the channel, but has never, in seventeen years of observation, overflowed the valley floor.

Sharp zigzags, oxbow bends, cut-offs, caving banks on the outside and bars on the inside of the bends are numerous.

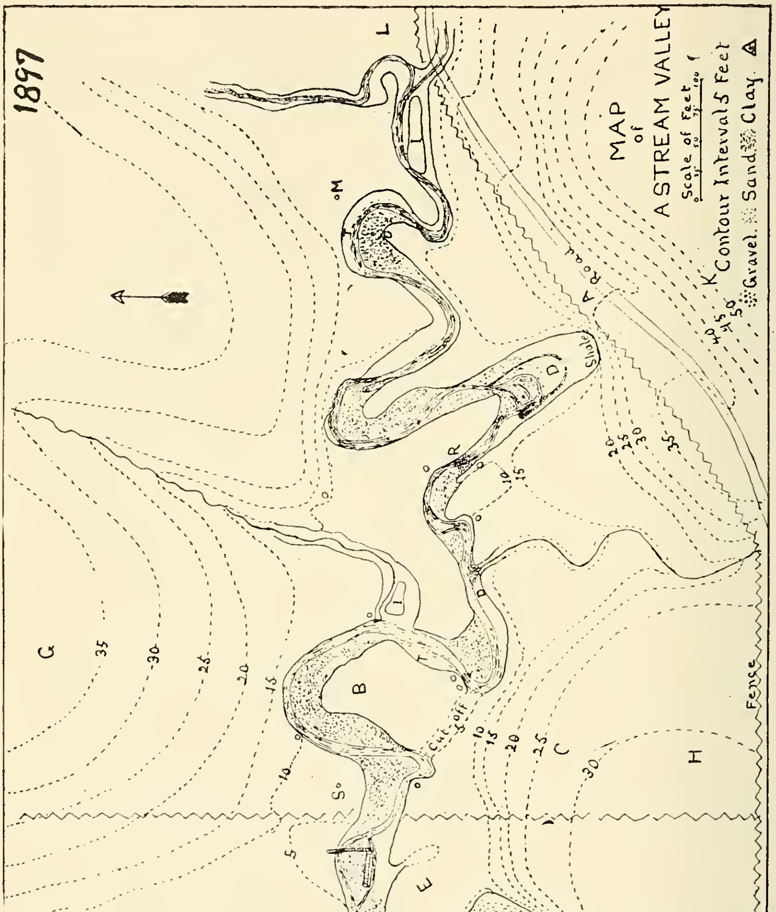
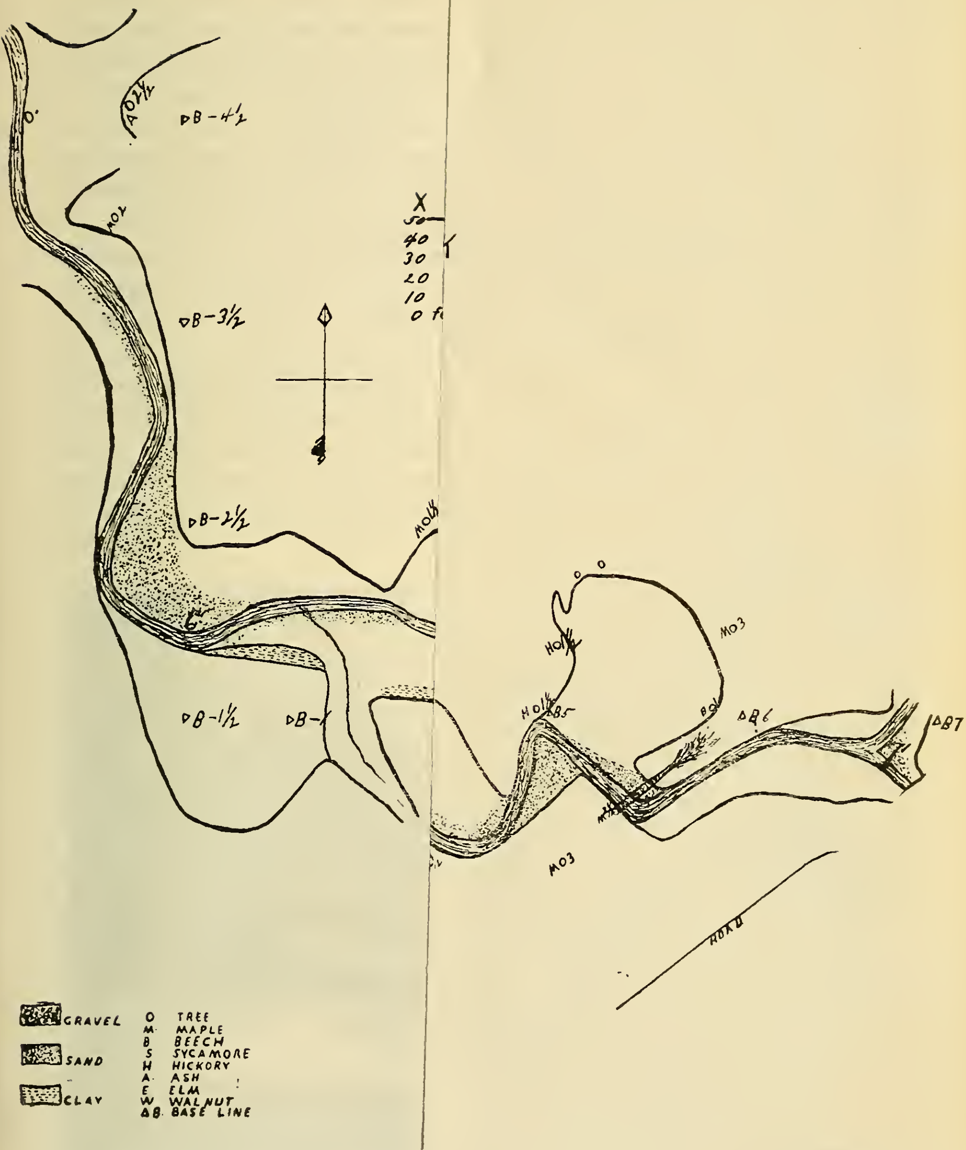


Fig. 1.

NORMAL BROOK.



ΔB-4½
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ΔB-2½
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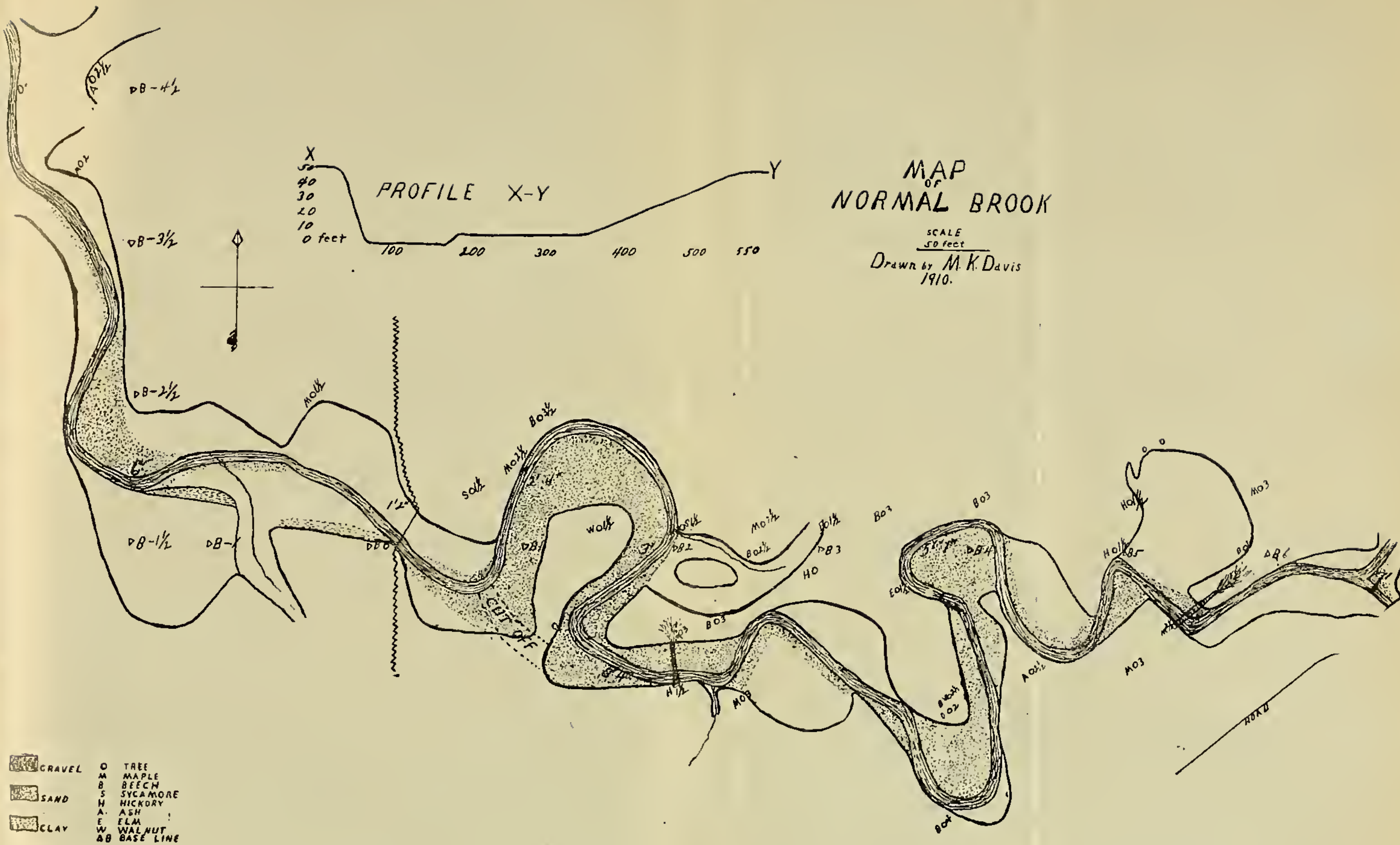
MAP
of
NORMAL BROOK
SCALE
50 feet
Drawn by M. K. Davis
1910.
PROFILE X-Y
X
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550
CUT OFF
ROAD
GRAVEL
SAND
CLAY
O TREE
M MAPLE
B BEECH
S SYCAMORE
H HICKORY
A. ASH
E ELM
W WALNUT
ΔB BASE LINE

Fig. 2

A detailed description of some of these features and the changes which have taken place in thirteen years, as shown upon the two maps, form an interesting demonstration of stream work.

The island at I has disappeared. The horse shoe near M has been cut off, a beech tree removed from its center, and the whole area converted into flood channel. The next bend to the west has been widened and rounded (all done at two or three spring freshets), and the neck nearly cut through. The sharp bend at D has also been widened and the tongue shortened. The cut-off channel across the neck of bend B, a foot deep thirteen years ago, has not been enlarged, and the cut-off, then apparently imminent by overflow, is now likely to take place soon by lateral erosion of the neck. The south bank opposite S has been cut back twenty-five feet, including a large beech tree. West of S the north bank has been cut back forty feet including a large maple. Near P the stream strikes and undercuts a boulder clay bluff, turns to the north and ceases to meander. The general result is a notable enlargement of the area of the flood channel floor, which has become a new flood plain, leaving the old one as a terrace.

Fig. 3.

The valley floor and sides are occupied by an open, park-like forest, consisting of oak, maple, elm, beech, hickory, basswood and other trees, mostly from two to three feet in diameter. The smallest one is eighteen inches and one beech is nearly four feet. The area has never been under the plow, and has for many years been used as a pasture. Evidently the stream channel is shifting rather rapidly from side to side, and the alluvial material has not been deposited in thin layers over the surface, but has been transferred from one side of the channel to the other by lateral corrasion and deposit. The trees do not check the process of lateral shifting in the least. If the stream comes against one it undermines and tips it over as readily as it cuts away its bank elsewhere. There is only one tree in the valley more than about 100 years old and that stands near the foot of the bluff. Therefore the inference seems justified that a complete shifting of the channel from side to side and a working over of all the alluvial material takes place about once every century.

The most puzzling question about this stream is the obvious one, what makes it so crooked? At ordinary stages it carries almost no sediment, and at flood it does not appear to be overloaded except on the inside of the bends. The valley is straight, the flood water channel is very crooked and the low water channel is still more crooked. The fall of the stream in 1,960 feet of length is seven feet, or at the rate of 19 feet per mile, and in the upper 1,360 feet is 22.5 feet per mile, which equals the average fall of the Colorado river through the Grand Canyon. The fall in the lower 600 feet is 10.3 feet per mile. The slope of the valley floor in 1,150 feet is 32 feet per mile, but in the upper 650 feet is 42 feet per mile. Therefore the stream is most crooked where the valley slope is steepest. Its law seems to be, the crookedness varies directly as the steepness of valley slope. This supports the conclusion of Jefferson that "maturely meandering streams may be regarded as finding their slope too steep."[1]

It works in easily eroded material and the extraordinarily crooked portion of it is just where it crosses the belt of sand dunes. These facts indicate that a temporary and local excess of load may be one of the factors concerned in the problem.

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[1] National Geographic Magazine, Vol. 13, Page 373.

Fig. 4.

Abandoned bends at high levels show that the stream has been meandering for a long period. The fact that it no longer overflows its valley floor, but only the channel floor, means that it is slightly intrenched, is making a new flood plain at a lower level, as the cross profile shows (Fig. 2), and leaving its former flood plain as a terrace. In intrenched meanders cut-offs are rare, because they occur only where a neck is cut through by lateral erosion. The cut-offs of Normal brook are made in this way and not by overflow across a neck. In such cases the meander belt has no self-limiting width, but is restrained only by the bluffs. In Normal brook the width of the belt is about thirty times the width of the low water stream and not more than five times the average width of the high water channel. The present base level for the brook is the surface of the gravel terrace in the Wabash valley. The brook once emptied directly into the river when it stood at a level ten or fifteen feet above the terrace. Therefore the brook has been subjected in post-glacial times to a fall of base level of that amount. Meanders acquired during a condition of higher base level and gentler slope may have been inherited and moderately intrenched by the present stream.

Fig. 5.

Fig. 6.

The Paleolithic, Neolithic, Copper and Iron Ages of Shelby County, Indiana.

By F. W. Gottlieb.

Exact date, I know not; but we will say at least 1,000 years ago. I will treat especially upon the mounds of Hanover township, known as Hog Back and Kinsley mounds. The former is 250 yards long, over 100 yards wide and was 65 feet at its highest point. As I study this prehistoric burial place I become convinced that it is a great deal of Nature's handiwork, dating back to the drift period, because of the large boulders imbedded in the great mass of choicest gravel. A valley between this mound and another very high ridge shows how the earth was taken therefrom and placed on top of the mound ridge, thereby forming a surface which caused the earlier white settlers to give it the name of Hog Back, much representing the razorback species. Old historic Big Blue River flows gracefully past the east side of the mound, which rises abruptly to the height of 65 feet. On the north end flows a spring of sparkling water, which has quenched the thirst of countless ages; even in this progressive period it is the camping and picnic ground for numerous persons each summer season.

The land where this mound is located was entered by a Mr. Chadwick in Freeport, a small isolated village near Morristown, where the South Illinois Indian trail crossed Big Blue River. There was at one time an appropriation made by the Indiana State Legislature for the improvement of Blue River up to this point, and on the opposite side of the river and a little below is a spot marked by the State Geologist where gold has been picked up, the retreat for many summers of Indiana's most famous author and poet, James Whitcomb Riley, and immortalized by him.

Some distance above the squat and burial-place of our pre-Columbian brethren which so beautifully overlooks the village lived a settler of pioneer fame by the name of Pouge, who is supposed to have been killed by the Indians that had stolen his horses, when he with his gun followed the trail northeast of Indianapolis to a stream which took its name after the


Hog Back Mound
Freeport Ind

settler. At this point it is claimed that he overtook the Indians and was killed, as he was never seen afterwards. But some years later a skeleton was found in a pit where a tree had uprooted, which was supposed to be the skeleton of the settler, being the last reminder of the Indians who no doubt buried their dead in sitting postures in Hog Back, prepared originally by their predecessors, the Mound Builders.

The mound is in an enclosure of about six acres always covered with blue grass and was undisturbed until fifteen years ago. Several very large beech trees are still standing on the same, also very large stumps of blue poplar trees. After the land was sold, the new owner at once began to haul gravel and great destruction has taken place. Many skeletons have been taken out and their bones, along with the gravel, have helped to make the many good roads of Hanover township.

Seven large spears and many ornaments of bone, mollusk, shale beads, ornamented bear teeth, polished but not pierced, Beaver, Ground Hog and Wildcat teeth have been found.

Exhibit 1. The skull of this solon of the past is one of the most perfectly preserved specimens taken from Hog Back. Oh, if he could only tell what his cranium once possessed in knowledge! He was no doubt a Mound Builder, as he was found in nearly the middle of the great ridge and about seven feet under the surface. The carelessness of the gravel diggers was unfortunate indeed, as no other part of him was saved and what artifacts might have been buried with him were lost.

The soul of the man
The organ of thought—
Tell me, if you can,
What this man might have wrought.

2. This broken Femur—see how it was stoved and how firmly it welded together. I would like to know the name of the prehistoric surgeon! I took up a skeleton on the highest point twelve years ago of a man no doubt 90 or 100 years old, judging the age from the teeth. He was a very large man. His jaws were so huge that I could place them on the outside of my jaw and move my chin very freely. He had a broken left rib which was lapped together and healed very nicely.

3. This banded Slate Bird Amulet, being the first of the slate artifacts that were found in the mound, is what archaeologists term the Duck, or Lucky Stone, and was tied on the bow of the boat to insure success for the day's hunt and catch.

4. This Mollusk shell, pierced with three holes, was upon the breast when it was found with the skeleton.

5. This beautiful banded slate ceremonial was unearthed one month ago. It is a very valuable addition to archæological science. I contend that this specimen is not a ceremonial tomahawk, but the ancient game stone, similar to the game of Diabolo recently revived over the world. A heavy sinew from the deer, such as the early Indians used for their bows, was no doubt placed through the unusually large square hole and then tossed into the air by means of a wand and kept in motion by applied science or practice. It shows very plainly where the strings wore grooves on the four corners of the hole through the ceremonial.

This mound looks very sad today, as many hundreds of loads of gravel are hauled therefrom every year and soon the abode of early man will disappear. I will halt here long enough to say that Indiana is very slow in taking up the matter of preserving her Indian Mounds, a subject in which I am deeply interested, and I will make an effort to call the attention of the next session of the Legislature to this important matter.

Fig. A.

Neolithic Age.

Showing the many different Banner stones, Gargets, and Ceremonials. The virgin and matrimonial stones in the center of the picture, the U shape being the virgin and the — the matrimonial. Pipes and bow-string makers, etc.

Fig. B.

Paleolithic Age.

These are the crudest of the stone age. Nearly all these stones are as they found them and applied them to their use, with a slight improvement, such as holes or sharpened edges.

Fig. C.

Neolithic Age.

Drills, spears, war arrows, etc.

Fig. D

Neolithic Age.

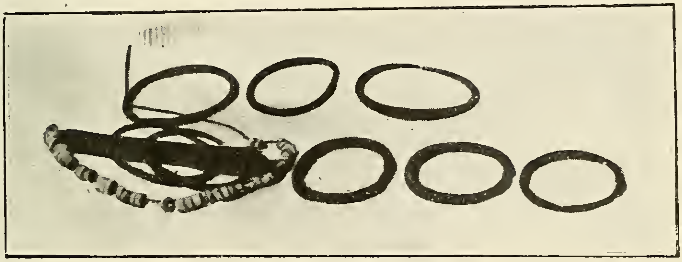
Showing the advanced stage of the stone art over the paleolithic. The tall stones are pestles used to grind their cereals; the long ones are mullers, used, no doubt, to roll out the dough, etc. Large spears, up to 7 and 8 inches, tomahawks, fleshers, tanners, etc.

COPPER AGE.

THE KINSLEY MOUND.

So named because an old gentleman by that name owned the land, which is now inside the corporation of Morristown, Indiana, Hanover Township.

We suspected this elevation to be a mound for years. Finally the land was sold and platted into town lots. Mr. Davis, who bought these certain lots began at once to haul gravel from the side of the mound, which is a perfect circle about 150 feet in diameter and not over seven feet high at the present, owing to the fact that it was under cultivation for many



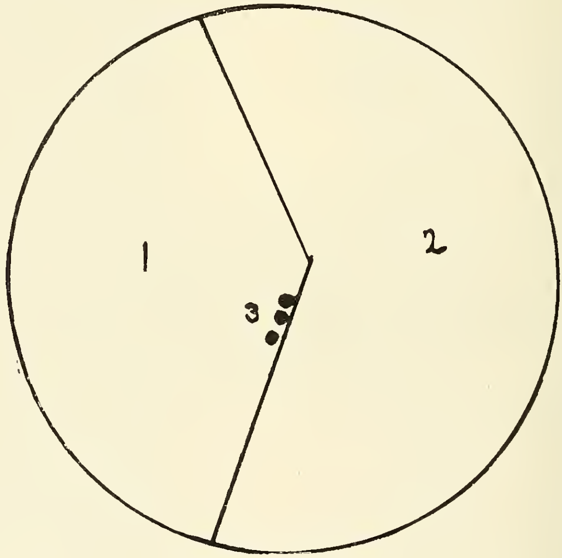
FROM KINSLEY MOUND.

years, which has worn it down several feet. Much to the surprise of the diggers, human bones began to appear, copper bracelets began to fall and tinkle, disclosing three bodies—that of a supposed Chief, his squaw wife and child squaw, having a total of 16 copper bracelets on their wrist-bones. (Of said number I possess 8 and show them to you.) Here are two wrist bones of the child, with two bracelets on them, as I found them myself. My companion obtained the other arm and the two bracelets, being a total of four that the child wore. We found over 200 beads of antler wampum in the dirt about the child's neck. (Of the same I show you over 50.)

Note the thickness of the bracelets about the wrists of the Chief, a size smaller about his no doubt conjugal squaw.

I have here some of the ash bed these bodies were buried in, which shows one inch thick in the soil. Also some splendid specimens of charcoal. The crania in general from this mound are in a miserable condition.

Just one-half of this conical mound has been destroyed. I may yet obtain more valuable information when the remainder has been destroyed. Would that I possessed the same; I would restore and fence it about, let blue grass reign supreme, erect a suitable monument to these solons of the copper age, which could be readily seen from the C. H. & D. R. R., being not over 100 feet from the track; but alas, there is too much profit in the gravel, and man of this flying machine epoch must have the cash.



KINSLEY MOUND.

1. This part excavated.
2. This part left intact.
3. Three bodies were removed.

The International Society of Archæologists, of which I am an ardent member, is taking up the Science of Archæology and spreading it all over the world, enlisting support everywhere, and hope to do away with this wholesale destruction of the monuments, thus preserving them for the care and study of future generations.

Now one word or more, why we find so often three bodies buried together, of man, woman and female child. This is my second observation, and others have related like observations to me. Did they cremate, or put to death first the favorite wife and female child when the chief and father died, to be buried with him, or what? What do you think, you members of this splendid Academy?

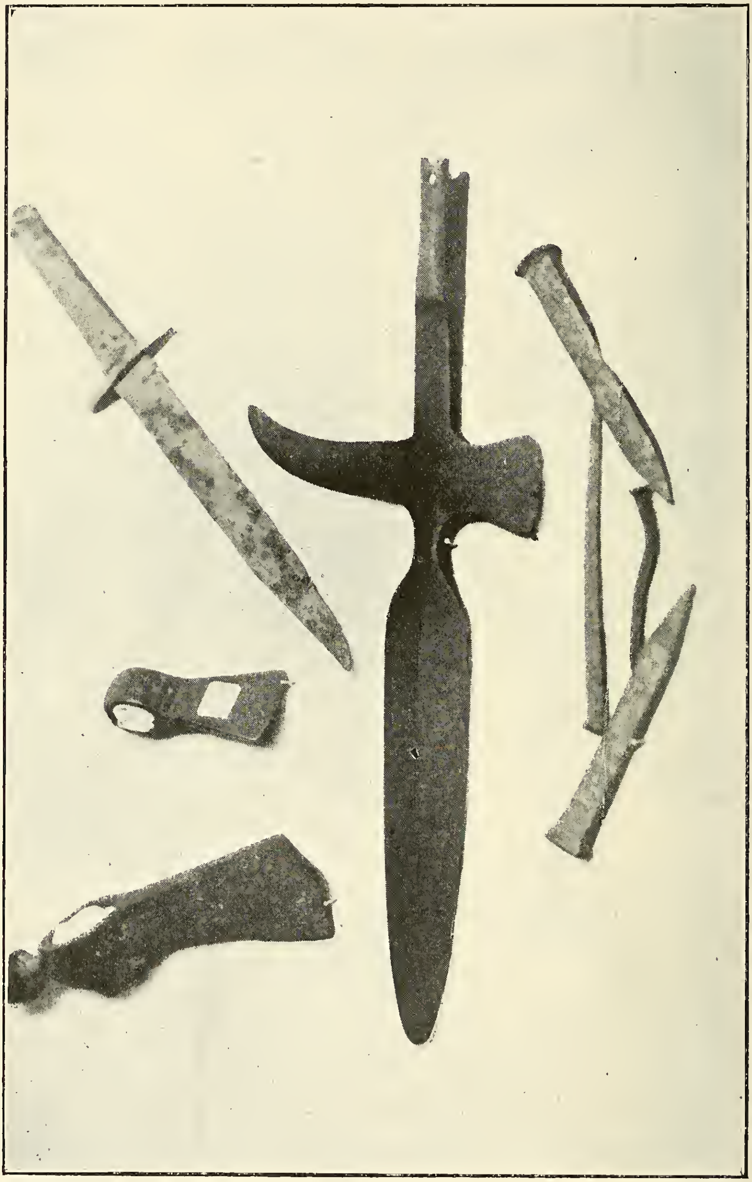
IRON AGE.

We are now in the Columbian era, when the Spanish and French and early English inhabited this section. The center weapon in the illustration is a very finely preserved Halberd, plowed up about ten years ago. An exact counter part of this Halberd mounted, with its original handle, I saw in the Cincinnati Art Museum, which was loaned to the said institution, having been handed down at least 250 years. It was used with great skill to spear, climb forts, chop away an opening through the then dense forests, etc.

The Spanish Bowie Knife was found recently in Morristown when digging for grading a hillside, by William Cremens.

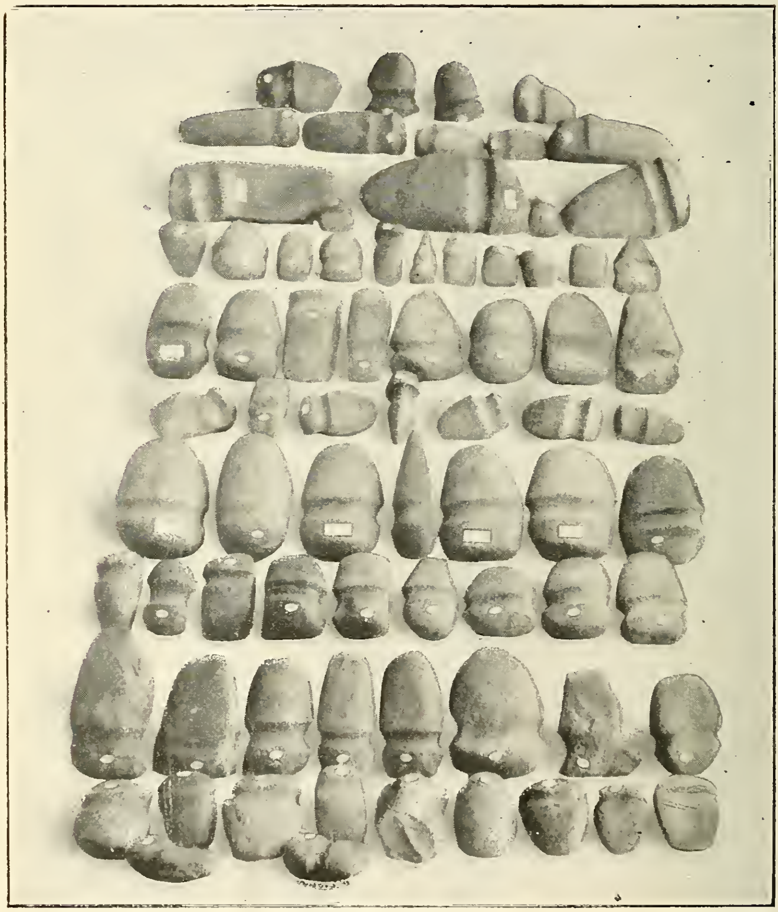
The Squaw Ax and peace pipe Tomahawk were both plowed up years ago and were no doubt made for the early Red Skins in this section, who were Miami and Ben Davis Indians, by the men that no doubt lost the Halberd. The early settlers, when on friendly terms, would exchange these handmade implements of Iron with the Indians for furs, pottery, etc.

The two Spikes shown are from the first railroad built in Indiana, known as the Knightstown & Shelbyville Railroad. An old settler tells me that it is 52 years since he last rode on it. It was a flat bar system, wooden sleepers and a flat iron rail was spiked on with these spikes, which were found by my friend L. Cole on his farm in Hanover Township. The road crossed Main street in Morristown, where stood the old depot, and the two nails shown were taken from the building when it was torn down. My stepfather (deceased), Collins Wilmot Griffith, the first mill wrighter and pattern maker, that superintended the building of the first Flour Mills

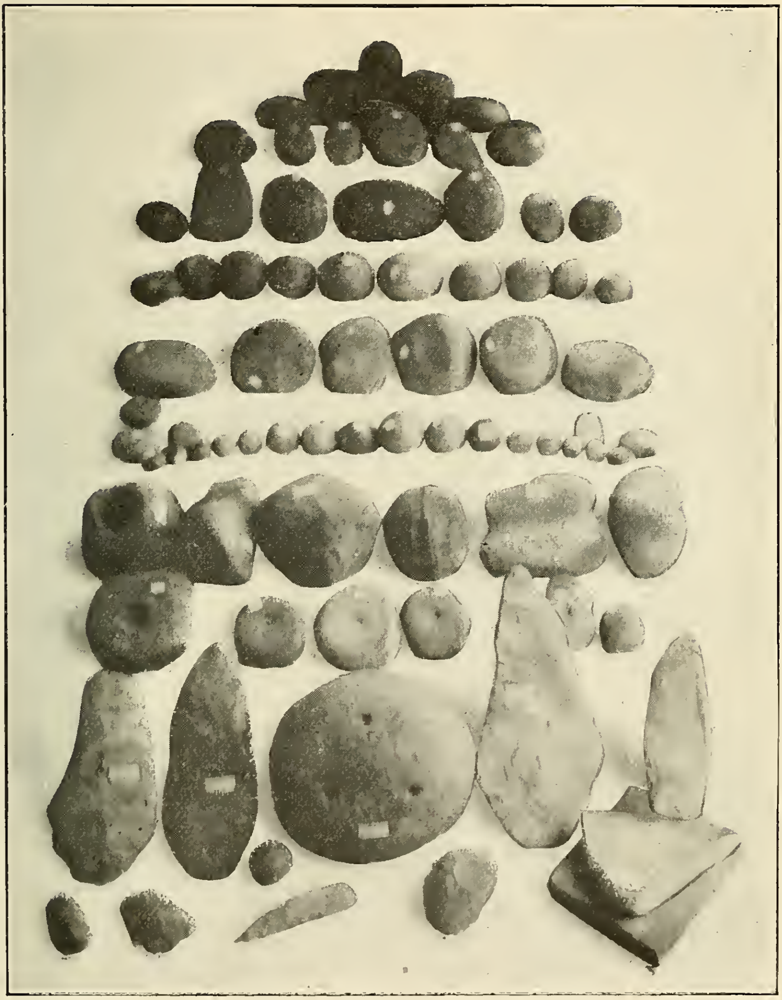


and Foundries in this part of the State, in his years of retirement was the owner of the Stage line which operated between Knightstown and Shelbyville. He also conducted the Hotel at Knightstown. The sad affair of building and putting this fast Railroad into operation was such competition that he soon lost his fortune tied up in horses and stages. He continued to conduct the Hotel and many belated passengers were his guests for several days at a time until the mishap on this slow Railroad was corrected.

Thus I bring my Iron Age to a close. I have brought you from the prehistoric past into history and there I close, with a mention of the progression of 75 years—the Telephone, Electrical Achievements, Phonograph. Wireless Telegraphy, Flying Machine.



GROOVED AXES.



PITTED STONES, GROOVED MORTARS, HAMMERS, ALTAR STONE, HOES AND HEARTH STONES.

CEREMONIALS.

CELTS, GAGES, CHISELS.

PESTLES, MULLERS, MORTARS.
FREDRICK W. GOTTLIEB.

Fauna of the Brazil Limestone.

By F. C. Greene.

Prof. Chas. W. Shannon of Brazil sent to the State University a collection of fossils which he said came from a limestone just below the surface at that place. Later Dr. J. W. Beede of the State University and Mr. L. C. Snider sent in other collections from the same limestone at somewhat different localities in the same vicinity.

The stratigraphic chart in the 33rd annual report of this department shows this limestone as occurring in Division II of the Indiana Coal Measures. In the 23rd annual report of this department, Ashley gives the following sections from this locality:

	Brazil. Sec. 29.		Ashley. Sec. 31.	
	Ft.	In.	Ft.	In.
Sandstone	?	?	?	?
Limestone	17	0	11	0
Shale	4	0	6	0
COAL, good	3	4	1	6
COAL, bone	1	2	0	0
Fire-clay	?	?	0	0
Shale			16	0

In other places in this vicinity, the limestone is only seven feet thick or may be wanting, while the underlying shale varies from 0 to 8 feet in thickness. The limestone is a dark-colored, bituminous stone, having an irregular fracture and the fossils are mainly white or light-colored. It is sometimes overlain by very fossiliferous, dark-colored, calcareous shale from which finely preserved specimens may be washed.

FAUNA.

1. Fusulinella Sp. Probably a new species.
2. Lophophyllum profundum M-E and H.
3. Zeacrinus sp. (plates).
4. Eupachycrinus tuberculatus Meek and Worthen.
5. Eupachycrinus sp. (fewer but larger tubercles).

6. Archeocidaris sp. (plates and spines).
7. Worm c. f. Spirorbis anthracosia Whitfield.
8. Worm sp. (represented by burrows in the shell of Productus costatus).
9. Fistulipora nodulifera Meek.
10. Stenopora spinulosa Rogers.
11. Stenopora ohioensis? Foerste.
12. Stenopora tuberculata Prout.
13. Stenopora c. f. cestriensis Ulrich.
14. Stenopora sp. Probably a variety of S. spinulosa.
15. Stenopora 2 species. Probably undescribed.
16. Fenestella limbata Foerste.
17. Fenestella modesta? Ulrich (reverse only shown).
18. Polypora whitei Ulrich.
19. Polypora spinulifera Ulrich.
20. Polypora sp. (resembles P. cestriensis somewhat but differing from it in having much longer fenestrules).
21. Pinnatopora sp. (reverse only shown).
22. Septopora pinnata Ulrich.
23. Septopora biserialis Swallow.
24. Rhombopora lepodendoidea Meek.
25. Streblotrypa distincta Ulrich.
26. Cystodictya carbonaria Meek.
27. Cystodictya sp. (resembles C. inequimarginata but has 5-6 rows of zoecia).
28. Prismopora sereata Meek.
29. Derbya crassa M and H.
30. Chonetes mesolobus N and P.
31. Productus cora var. americana Swallow.
32. Productus punctatus Martin.
33. Productus costatus Sowerby.
34. Productus wabashensis N and P.
35. Productus muricatus N and P.
36. Productus sp.
37. Dielasma bovidens Morton.
38. Spiriferina kentuckiensis Shumard.
39. Spirifer cameratus Morton.

40. Spirifer rockymontanus Marcou.
41. Reticularia perplexa McChesney.
42. Hustedia mormoni Marcou.
43. Seminula argentea Shepard.
44. Aviculopecten occidentalis Shumard.
45. Aviculopecten hertzeri? Meek.
46. Myalina recurviorostris M and W.
47. Macrodon carbonarious Cox.
48. Schizodus harii Miller.
49. Astartella varica.
50. Allorisma terminale? Hall.
51. Pelecypod sp.
52. Cephalopod sp. (probably Tainoceras occidentalis Swallow).
53. Griffithides scitula M and W.
54. Fish tooth (fragment).

The Brazil limestone is probably to be correlated with the Fort Scott limestone of Kansas, since a similar fauna has been noted by the writer from this horizon (Henrietta limestone) of Missouri and southeast Iowa.

Preparation of Ether.

By P. N. Evans.

It is commonly stated that in the preparation of ether by running alcohol into sulphuric acid kept at about 140 deg. Centigrade, while the operation is nominally a continuous one, the acid acting catalytically, the volume of ether obtainable amounts to only about six times that of the acid used before the action is seriously impaired, soon to cease altogether.

Various causes for this limitation have been suggested, including the accumulation of water formed in the main reaction, the formation of sulphuric and sulphonic esters rendering the acid unavailable, and the actual destruction of the acid by reduction to sulphurous acid by the organic compounds present. Little or no experimental evidence is given in support of any of these hypotheses, and the present difference of opinion leaves the question still open.

With the assistance of Miss Lena Sutton the writer is attempting to get more definite information as to the actual limits of the reaction and their cause or causes. At the time of writing the work has not proceeded far enough to provide the solution of the problem, but it has already been learned that instead of the efficient limit being reached when the volume of the ether amounts to about six times that of the acid used there is no diminution of efficiency at about fifty times the volume, when ordinary commercial alcohol and acid are employed. It has been found, too, that the accumulation of water formed in the reaction cannot be the inhibiting factor, for it has been learned that it is practicable to start with highly diluted acid and obtain the usual results, the acid evidently becoming concentrated to the necessary degree by loss of water at the temperature ordinarily employed.

In order to determine the proportions of ether, alcohol and water in the successive distillates, they are submitted to fractional distillation, and the results compared with those from known mixtures in the proportions possible under the conditions of the experiment, assuming the alcohol used to have undergone the reaction with varying degrees of completeness.

It is hoped to obtain further experimental evidence bearing upon the problem during the present academic year.

The Surface Tension Temperature Coefficient.

By Arthur L. Foley.

Some fifteen years ago the author described a method of finding the surface tension of liquids by determining with a balance the force required to pull a frame of mica from the liquid.[1] A mica frame, cut in the form shown in Fig. 1 is suspended from one arm of a sensitive balance and the lower edge (a-b) of the upper strip of mica is brought into contact with the liquid. The liquid is then gradually lowered while the pointer of the balance is kept at the turning point by adding weights to the other pan. Eventually the downpull of the liquid and film is exceeded by the weights on the other arm of the balance, the mica frame is pulled suddenly upward, and the film breaks. The frame is then weighed while still in the liquid. The difference between the two weights gives what is called the maximum weight, from which the method takes its name.

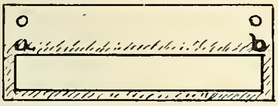


Fig. 1.

The surface tension is given by the equation

$$T = \frac{wg}{2(l-t)} + \frac{dl^2t^2g}{4(l-t)} - \frac{ltg}{4(l-t)}\sqrt{d^2l^2t^2 + 4w(l-t)d}. \qquad (1)$$

Where T=surface tension in dynes.

w=maximum weight.

l=length of frame (between legs).

t=thickness of frame.

d=density of liquid.

g=acceleration due to gravity.

When the frames are thin one may use the simple equation

$$T = \frac{wg}{2l}. \qquad (2)$$

The maximum weight can be determined again and again with surprising uniformity. Even when one uses mica frames differing greatly in

[1] Proceedings of the Indiana Academy of Science, 1895, p. 67.
Physical Review, Vol. 3, No. 5, 1896, p. 381.

thickness the values of the surface tension calculated by equation (1) are quite concordant. In the article already referred to the author gives results for frames ranging in thickness from .0013 cm. to .02067 cm., the greatest variation being less than six-tenths per cent. Equation (2) gave results with a maximum range of four per cent. the difference being greatest for thick frames. But in practice it is not necessary to use thick frames. In the case of the variation of the surface tension with temperature all the measurements may be made with a single frame. In this experiment the frame was .0102 cm. thick and 6.642 cm. long.

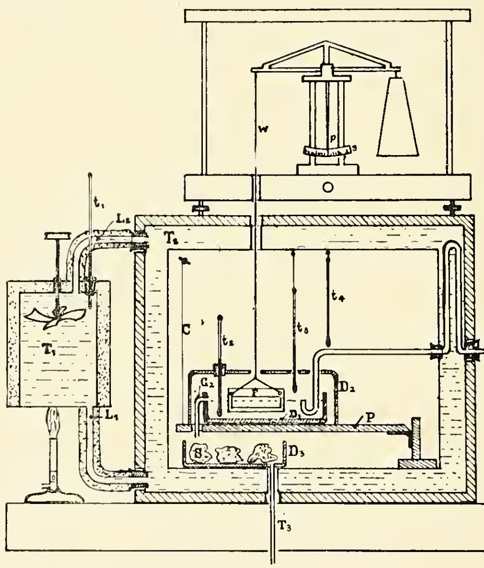


Fig. 2.

Fig. 2 shows the arrangement of the apparatus for measuring the temperature coefficient of the surface tension of water between room temperature and 80°. A mica frame F was hung on a wire W attached to one arm of a balance—sensitive, at this load, to .002 mg.. The balance itself rested on a wooden box shown in section. This box had a door in front (practically air tight) with a double glass window through which the apparatus inside could be seen and the thermometers read. The wooden box enclosed a double walled tin box or tank T_2 with walls about eight centimeters apart on all sides except in front of the glass door. T_1 was a copper vessel or tank connected by lead tubes L_1 and L_2 to the tank T_2. Both tanks were filled with oil. The oil in the tank T_1, heated by one or more bunsen burners, passed through the tube L_2 into the tank T_2 and finally back through L_1 into T_1. A stirrer, driven by an electric motor, aided in producing a rapid circulation of the oil. Tank T_1 and tubes L_1 and L_2 were wrapped with several layers of asbestos paper.

From a flask not shown in the figure water was siphoned to and through the tube G_1 into the evaporating dish D_1. An overflow G_2 served to keep constant the depth of the water in the dish. The excess of water dropped on sponges S in an evaporating dish D_3, itself drained by the tube T_3. The sponges served to keep the space inside the box saturated with watery vapor, or nearly so. An inverted evaporating dish D_2 served to enclose almost completely the frame and liquid and thus insure the saturation of the space about the film on which the measurements were made.

The dish D_1 rested on a wooden platform P supported at one end by a hinge and at the other end by a cord C passing over a cylindrical metal rod which extended to the outside of the box. The height of the water surface was slowly raised or lowered by twisting the rod.

A thermometer t_1 gave the temperature of the oil, t_2 the temperature of the water, t_3 the temperature of the space immediately above the water, and t_4 the temperature of the space outside the inverted evaporating dish. No measurements were made when the thermometers t_2, t_3, and t_4 differed by more than a few tenths of a degree. This necessitated a wait of from one to five hours between readings at different temperatures. Three series of readings were taken, each requiring a continuous run of from ten to thirty-six hours—depending upon the number of observations made.

Owing to the condensation on the wire W where it passed through the opening in the tank T_2 it was not practicable to carry the observations higher than 80°. An effort was made to prevent this condensation by driving gently through the opening a stream of warm air from the outside. But this interfered somewhat with the action of the balance and the saturation of the space inside. It did not occur to the writer at the time to try heating the wire by means of an electric coil.

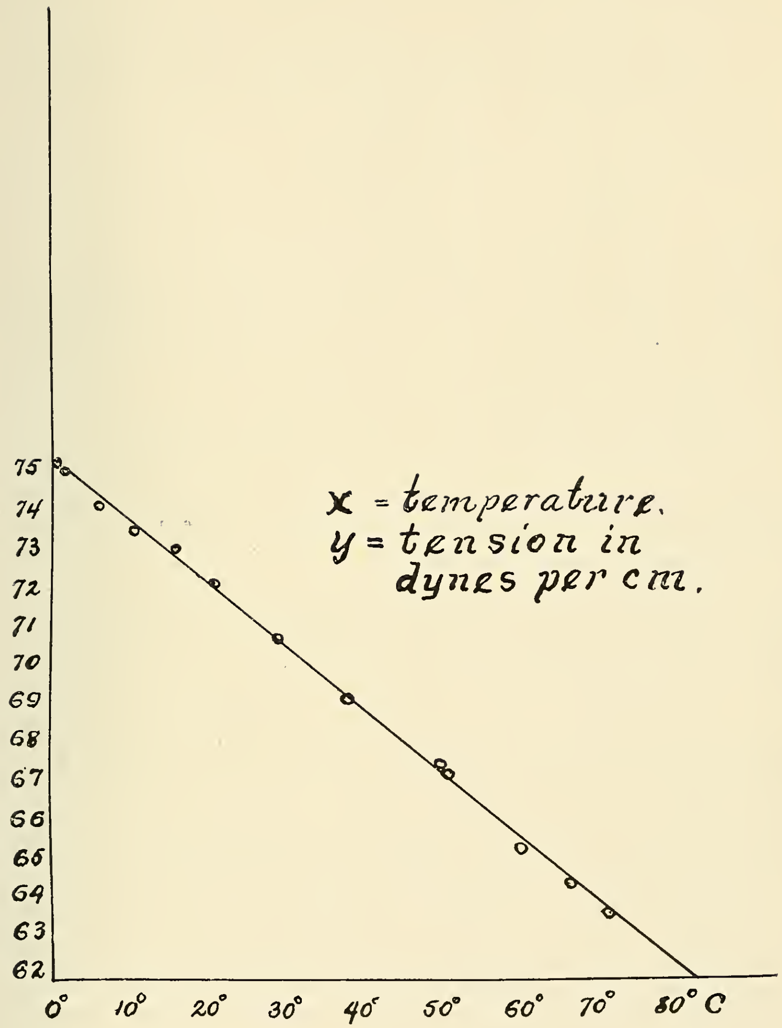
For temperatures below room temperatures the asbestos was removed from the tank T_1 and the tank was surrounded by a large vessel containing water and ice, or ice and salt, depending on the temperatures required in the tank T_2.

The water used in this experiment was first distilled in the usual copper still, then with potassium permanganate in glass, then twice again in glass. Just before using the water was boiled for fifteen minutes to drive off absorbed gases, and then rapidly cooled by placing the flask in ice water. The water was siphoned from the flask through a glass siphon with a cock which permitted the flow to be adjusted at will. Before opening the cock the water in the flask was each time brought to approximately the temperature indicated by the thermometer t_4. It was then passed through the tube G_1 (which had a length of some fifty centimeters inside the oil) into the dish D_1. Sometimes the measurements were made with the water in D_1 at rest, sometimes with the water flowing very slowly from the tube, this giving a fresh surface as free as possible from absorbed gases or contamination of any kind.

The author feels sure of all his data except his temperature measurements. The thermometers used were bought for high grade instruments. It was the intention to calibrate them at the conclusion of the experiment. By accident they were placed with some others of the same kind and so could not be identified.

The results obtained in this investigation are given in the following table and are plotted in Fig. 3.

Temperature of the Water—	Tension in Dynes per cm.
1.0°	
1.4	74.95
6.6	74.176
10.7	73.667
16.5	73.087
21.8	72.20
29.2	70.795
37.3	69.32
50.4	67.36
51.0	67.27
61.6	65.50
67.5	64.45
72.6	63.71



x = temperature.
y = tension in dynes per cm.
75
74
73
72
71
70
69
68
67
66
65
64
63
62
0°
10°
20°
30°
40°
50°
60°
70°
80° C

Fig 3.

From the plot one obtains the following values:

Surface tension at 0° C.=75.5 dynes per cm.

Surface tension at 18° C.=72.6 dynes per cm.

Surface tension of 80° C.=62.6 dynes per cm.

Temperature coefficient=.161 dynes per cm.

T. Proctor Hall[2] gives the following values:

Tension at 0° C.=75.48 dynes.

Tension at 18° C.=72.96 dynes.

Tension at 80° C. (calculated)=64.28 dynes.

Temperature coefficient=.14 dynes.

Hall tabulates the results of nineteen different investigations by fourteen investigators giving a mean of all of Tension=75.4 dynes at 0° C. and temperature coefficient ranging from .141 dynes to .204 dynes per cm. Hall adopts .14 dynes as the most probable value.

It will be observed that the author's result for the tension at zero temperature agrees with the results obtained by others, but that his values at higher temperatures are considerably lower, giving a much larger temperature coefficient. The differences are entirely too large and too regular to be attributed to experimental errors.

Hall claims that absorbed gases tend to raise the surface tension of water and to increase the temperature coefficient. He claims also that the surface tensions of different samples of water are not the same. The author rather inclines to the view that the smaller values obtained at higher temperatures in this investigation are due to the fact that the measurements were made on water in contact with air saturated with watery vapor, while the conditions under which most of the other investigations have been made give the tension of water in contact with moist air, but not saturated air. Perhaps the actual temperature of the film under such conditions is not given correctly by a thermometer placed in the liquid. Evaporation into the air lowers the temperature of the surface film—possibly considerably below the temperature of the body of the liquid. Whatever the actual magnitude of this effect may be, it tends always to give too high values for the surface tension at high temperatures—the drier the air the higher the values.

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[2] New method of measuring surface tension. Philosophical Magazine, November, 1893, Vol. 36, p. 412.

Objections to Laplace's Theory of Surface Tension.

(Abstract.)

By Arthur L. Foley.

Laplace's Theory of surface tension attributes the contractile force of liquid films to the attraction of the molecules immediately below the surface of the liquid for those on the surface, producing a tendency for the surface molecules to move into the interior. The magnitude of this force would depend on the curvature of the surface and would be greater at a convex surface than at a flat or concave surface. Consequently the rise of water in a capillary tube would be due to the fact that the downward pressure of the film outside the tube is greater than the downward pressure of the film inside the tube.

This theory does not call for a negative pressure under the film inside the tube. It calls for a positive pressure, but slightly less than the downward pressure outside. The liquid then would be *forced up the tube by the outside film pressure.* It would appear then that any variation of the pressure either inside or outside the tube should be followed by a change in the height of the capillary column. Some simple experiments give results that are at variance with the theory.

Take a long capillary tube with its lower end extending some distance into the water and note the height of the capillary column. Drop some soap solution on the water outside the tube and thus lower the tension outside If the liquid is supported by the excess of pressure outside the tube, the height of the capillary column should be lessened. On the contrary the height remains constant for some time—hours even—until the solution has had time to diffuse into the tube.

Repeat the experiment this time introducing the soap solution into the capillary tube by means of a very fine capillary tube. The tension inside the tube being reduced (demanding a reduced pressure inside) and the outer pressure remaining constant, it would seem that the excess of the outside pressure would be increased and that the water should therefore rise in the capillary. Instead of rising it immediately falls.

The Variation in the Ratio of the Specific Heats of a Gas at the Temperature of Liquid Air.

By C. M. Smith.

Introduction.—The value of the ratio of the specific heat of a gas at constant pressure, to the specific heat at constant volume, $k = \frac{C_p}{C_v}$, has occupied the attention of physicists since the time of Newton. It was well understood by him that the values for the velocity of sound in a gas as calculated from his formula $V = \sqrt{\frac{elasticity}{density}}$, were not in accord with observed values, and being impressed by this discordance he was moved to make certain violent assumptions concerning the relative magnitudes of the gas molecules and the inter-molecular spaces, together with the relative velocities of sound in each. The true explanation of the discordance was first suggested by LaGrange, who pointed out that the elasticity of a gas might be augmented faster than its density, under compression, although it remained for LaPlace, in 1816, to develop the complete theory, and elucidate the necessity for regarding the adiabatic changes in volume, the modified equation being $V = \sqrt{\frac{elasticity}{density} \times k}$, where k is the ratio of the adiabatic and isothermal elasticities, likewise the ratio of the specific heats. Since that time more than a score of investigators have occupied themselves with the determination of the value of k[1], under the various conditions of temperature and pressure, and the importance attached to the determination of k will be apparent from the following considerations.

With a value of k assumed as known, its use in Newton's equation is convenient for studying various physical constants of a gas, and in small quantities of the gas, values of the velocity of sound and specific heats may be determined or compared. Furthermore a knowledge of the

[1] For an exhaustive review of the history of the problem, see Maneuvrier, Jour. de Physique, 4, 1895.

value of k is important because of its entrance into several of the fundamental equations of thermodynamics, and also because it furnishes an excellent criterion for the correctness of the assumptions made in the kinetic gas theory, concerning the distribution of the energy within the molecule. In view of these intimate correlations of the value of k with other fundamental factors it is important to study its variation under different conditions of pressure and temperature for the same gas.

For constant pressure Wüllner[2] found practically a constant value of k between 0° and 100° C., for air. Witkowski[3] has found evidence of a variation in k with both temperature and pressure, from theoretical considerations. Luduc[4] shows that k should decrease with rising temperature and with falling pressure. Stevens[5] finds a value of 1.34 for k at 1000°, and Kalähne[6] shows that k decreases with rising temperature, reaching a value 1.39 for 900°. S. R. Cook,[7], working with liquid air temperatures, finds the value of k for air to be 1.35 (nearly), and Valentiner[8] in an exhaustive study of the dependence of k in nitrogen upon pressure, at liquid air temperatures, finds the value of k to increase, approximately in proportion to the ratio of the pressure to the saturation pressure for the temperature used.

In this connection it was suggested to the writer by Professor Röntgen, that a study of the value of k should be undertaken for constant pressure and liquid air temperature, and under his direction the present work was carried out during the winter and spring semesters of 1901, in the Physical Institute at Munich. Two series of observations were carried through:

I. For constant pressure, the ratio of values of k for the temperatures of melting ice and boiling water was determined, the gas used being air, free from moisture and CO_2. Values under these conditions had been determined by Wüllner (loc. cit.), and were here repeated as a means of checking the method.

II. For constant pressure, the same ratio was determined over a range of temperature from that of the room, about 20° C., to that

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[2] Ann. der Physik 4, 1878.
[3] Sci. Abs. 3, 1900, p. 387.
[4] Sci. Abs. 3, 1900, p. 29.
[5] Sci. Abs. 4, 1901, p. 847.
[6] Ann. der Physik 11, 1903, p. 225.
[7] Phys. Rev. 23, 1906, p. 232.
[8] Ann. der Physik 15, 1904.

of liquid air, boiling freely under atmospheric pressure, about —190° C., the gas in this series being pure nitrogen.

Values were calculated for both series using the simple relations given in equation (6), and for series I the results were in close agreement with those of Wüllner. The assumption that Gay Lussac's law holds for nitrogen at low temperatures was however regarded as questionable, and results for series II were not at that time published. Subsequently the density-pressure relation for low temperatures was investigated for nitrogen by Bestelmeyer and Valentiner[9] in the Institute at Munich, and resulted in the establishment of the following empirical relation between pressure volume and temperature:—

$pv = h_1T - (h_2 - h_3T)p$, where T is the absolute temperature, p is the pressure, and v is the specific volume, the constants having values $h_1 = 0.27774$, $h_2 = 0.03202$, and $h_3 = 000253$. This relation introduced into the general equations gives (13). Making use of (13) the data of series II have been recomputed, and the results are given in table IV.

Subsequent to the experimental work of I and II, Valentiner[10] has made use of the same apparatus used by the writer, with certain modifications and improvements, for investigating the dependence of k upon pressure, for nitrogen, at liquid air temperatures.

THEORY.—The method used was that of Kundt's dust figures. Two glass tubes, maintained at different temperatures, had set up in them systems of standing waves by means of the longitudinal vibrations of the same glass rod. The frequency of the waves was the same within both tubes, and from measurements of the wave lengths, as shown by the dust figures, the variations in k could be determined.

The velocity of sound in any homogeneous medium is given by the equation

$$V^2 = -v^2 \frac{\partial p}{\partial v} = 4n^2\lambda^2. \qquad (1)$$

where v is the specific volume, and p is the pressure, the negative sign meaning that a decrease in pressure corresponds to an increase in specific volume. It must be remembered that the standing wave in the tube has a wave length half as great as that for the progressive wave of the same

[9] Ann. der Physik, 15, p. 61.
[10] Ann. der Physik, 15, p. 74.

frequency, and throughout λ will be used to mean the inter-nodal distance for the systems of standing waves. For a perfect gas the adiabatic equation *(pv^k=constant)* must be used, whence

$$\frac{\partial p}{\partial v} = -\frac{pk}{v}. \tag{2}$$

Substituting this value in (1)

$$V^2 = \frac{v^2 pk}{v} = kpv = 4n^2\lambda^2. \tag{3}$$

Let equation (3) refer to the tube B, Fig. 1, in series I, which contains air, and is at 0° C., and let a similar equation with subscripts apply to the tube A in the steam bath.

$$V^2{}_1 = k_1\, p_1\, v_1 = 4\, n^2{}_1\, \lambda^2{}_1. \tag{4}$$

Dividing (4) by (3) and solving for the ratio $\frac{k_1}{k}$.

$$\frac{k_1}{k} = \frac{\lambda^2{}_1\, v}{\lambda^2\, v_1}. \tag{5}$$

From Gay Lussac's law specific volumes are directly proportional to absolute temperatures, whence

$$\frac{k_1}{k} = \frac{\lambda^2{}_1\, T}{\lambda^2 T_1}. \tag{6}$$

From (6) the results given in table I are calculated.

For series II however, using nitrogen at liquid air temperature, the p–v–T relation to *Bestelmeyer and Valentine was used,*

$$p\ v = 0.27774\ T - (0.03202 - 0.000253\ T)\, p \tag{7}$$

Substituting in the fundamental equation

$$\left(\frac{\partial p}{\partial v}\right)_Q = k \left(\frac{\partial p}{\partial v}\right)_T \tag{8}$$

the value of $\frac{\partial p}{\partial v}$ for constant temperature, as determined by differentiating (7),

$$\left(\frac{\partial p}{\partial v}\right)_Q = \frac{k\ p}{v + (h_2 - h_3\ T)} \tag{9}$$

and substituting this in (1).

$$V^2 = \frac{v^2\, k\, p}{v + (h_2 - h_3\, T)} = \frac{k\, p^2\, v^2}{h_1\, T} = 4\, n^2\, \lambda^2 \tag{10}$$

Writing equation (10) with subscripts referring to the tube B Fig. 1, as used in series II with nitrogen, at a temperature of liquid air,

$$\frac{k_1\, p^2{}_1\, v^2{}_1}{h_1\, T_1} = 4\, n^2{}_1\, \lambda^2{}_1 \tag{11}$$

Dividing (11) by (3),

$$\frac{k_1\, p^2{}_1\, v^2{}_1}{k\, p\, v} = \frac{4\, n^2{}_1\, \lambda_1\, h_1\, T_1}{4\, n^2\, \lambda^2} \text{ whence } \frac{k_1}{k} = \frac{p\, v\, h_1\, T_1\, \lambda^2{}_1}{p^2{}_1\, v^2{}_1\, \lambda^2} \tag{12}$$

For normal conditions $pv = 76\ (1 + at)$, whence

$$\frac{k^1}{k} = \frac{\lambda^2{}_1}{\lambda^2}\, 76\, (1 + a\, t)\, \frac{h_1\, T_1}{p^2{}_1\, v^2{}_1} \tag{13}$$

The product $p_1^2 v_1^2$, referring as it does to nitrogen at liquid air temperature, must be computed from the empirical equation (7). Equation (13) is used for the calculation of results for series II, given in table IV.

Description of Apparatus and Method.—A general view of the apparatus as mounted for use is shown in Fig. 1, the essential features of which are shown in Fig. 2. Two glass tubes, A and B, Fig. 2, about 3.2 cm. in diameter, were bent at right angles, about 30 cm. from the ends, the horizontal portions being about 80 cm. long. These were mounted on a rectangular frame of wood, a a a a. This frame was hung with its plane vertical, and was capable of rotation about a pivot at the point O. The entire structure could be tilted forward slightly about an axis XX'. A glass rod e f g, 100 cm. long, with enlarged ends, was clamped at points ¼ and ¾ of its length from its ends, the supports for the rod at these points being of rubber, and serving at the same time to close the ends of the tubes. Through these rubber stoppers were passed small delivery tubes, for introducing the gas used. Adjustable pistons were inserted through similar rubber stoppers at c and d. The upper tube was surrounded by a double walled vessel made of tinned copper, and covered with a layer of heavy felt. This vessel had a closely fitting double cover, provided with mica windows through which the thermometers were read. It was also provided with inlet, outlet and drainage tubes, so that steam could be passed in and the temperature of boiling water indefinitely maintained about the enclosed tube A. A long trough was made of such dimensions that it could be raised up about the lower tube B, and when filled with melting ice the temperature of B could be held at 0° throughout the necessary time interval. For the series II, a trough of special design to contain liquid air was used. This was made of three layers of thin sheet tin, with

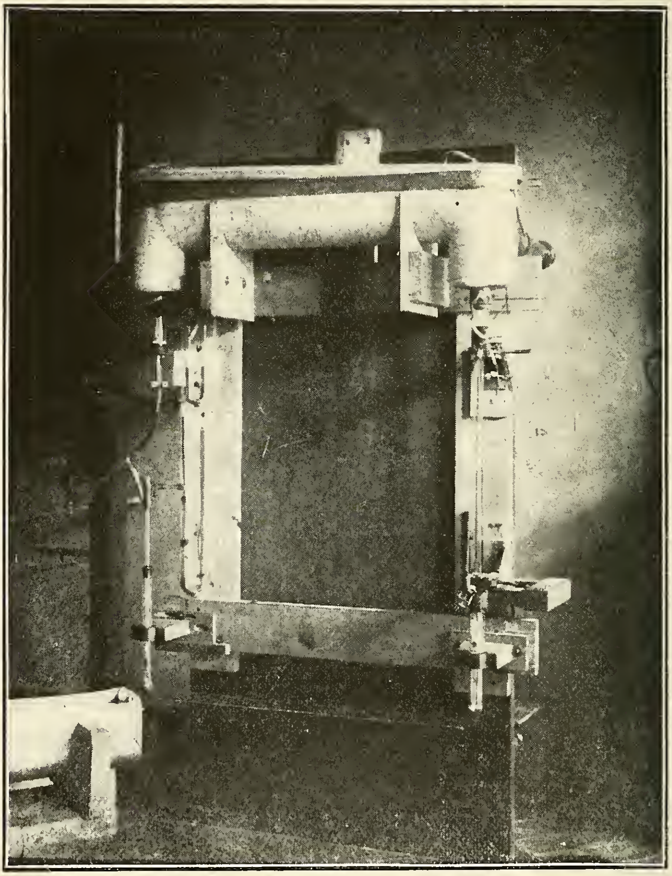

Fig. 1.

a U shaped cross section, nested together with thick layers of felt between. This is shown in the lower part of Fig. 1.

A small quantity of anhydrous quartz powder was placed in the tubes A and B, and uniformly distributed in a thin line along the bottom of the tubes by rocking the frame about O, and gently tapping the tubes with a pencil. After this linear distribution of the powder the entire structure was tilted forward slightly about XX′, and the line of the powder was made to seek the lowest part of the tubes by gentle tapping. On tilting the frame back to its vertical position, the line of powder was raised slightly along the side of the tubes, and when the glass rod e f g was rubbed at its middle point with a piece of moistened flannel, its longitudinal vibration was communicated to the gas in both tubes, setting up systems of

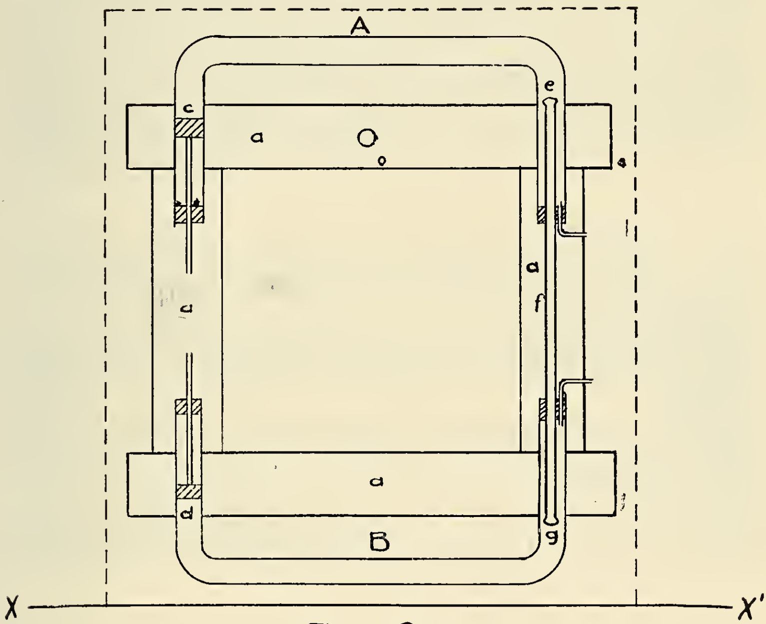

Fig. 2

stationary waves, and causing the powder to fall down at the points of maximum disturbance as shown in Fig. 3. These festoon like figures were sharp and uniform, and capable of accurate measurement, the inter-nodal distances giving the wave lengths of the standing waves within the tubes. Each of the tubes carried near the ends of the horizontal portions, a pair of felt covered brass rings. To the under side of these rings could be quickly attached by means of set screws, the brass meter scale for measuring the figures. A sliding sleeve which could be slipped over the tube was provided with a vernier reading to one-tenth mm., which played over the brass scale beneath, and on the sleeve was a fiducial line, in the form of a fine black wire. Three independent settings were made on each nodal point, the mean being taken as the position of the node. Since the figures were formed at temperatures different from those at which they were measured, the corresponding corrections for the expansion and contraction of the glass tubes were applied.

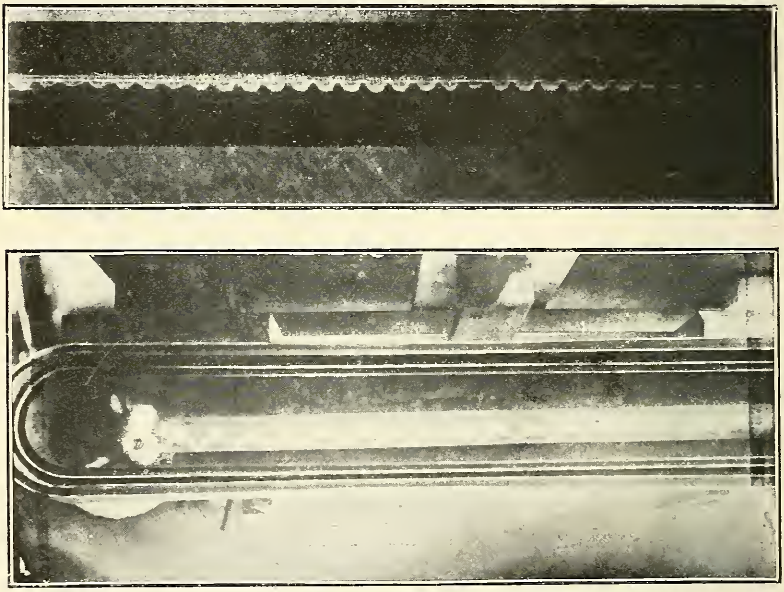

Fig. 3.

From such a series of measured inter-nodal distances the most probable value of the wave length was calculated from the formula,

$$\frac{(n-1)(a_n-a_1)+(n-3)(a_{n-1}-a_2)+\ldots\ldots\ldots\ldots}{\frac{n(n^2-1)}{1.2.3}}$$

where n is the number of settings, and a_1-a_2-a_3 are the respective settings.

The writer is indebted to Mr. P. P. Koch for a complete calibration of the brass scale used, in terms of the standard meter bar belonging to the Institute. Corresponding corrections have been computed and applied to all the measurements of both series.

PROCEDURE, SERIES I.—For this series of measurements the tube A was kept at steam temperature, while the tube B was packed in melting ice. The tubes were first carefully cleaned, washed with acid and alkali solutions, rinsed and dried, then mounted in place as in Fig. 2. Dry air free from CO_2 was drawn through them for some time, meanwhile gently warming them with bunsen burners. A small amount of the quartz powder, previously heated and cooled in a dessicator, was introduced, and the dry air suction continued for some time. The apparatus was then rocked and tilted as described above in order to effect a proper distribution of the powder, steam was admitted about A and the ice bath placed about B. After a period ranging from one to two hours, with both tubes open to the atmosphere through the drying train, the glass rod was rubbed, the temperatures and atmospheric pressure were observed and the steam and ice baths were withdrawn. After some hours the figures were measured in the manner above described. The thermometers used were frequently compared with standards, and the temperature in the steam jacket was constantly checked from standard barometer readings. One complete set of average wave length measurements is given in table I, and the data for eight such experiments, together with calculated values of $\frac{k_0}{k_{100}}$ are given in table II.

Tube A, in Steam.		*Tube B, in Melting Ice.*	
55.43	λ	63.73	λ
93.50	38.07	96.47	32.74
132.13	38.63	129.23	32.76
170.37	38.24	162.03	32.80
208.80	38.43	194.50	32.47
246.80	38.00	227.60	33.10
285.13	38.33	260.80	33.20
323.47	38.34	293.77	32.97
361.60	38.13	326.03	32.26
399.95	38.35	358.97	32.94
438.17	38.22	391.63	32.66
476.23	38.06	424.93	32.30
514.33	38.10	457.87	32.94
553.10	38.77	490.50	32.63
591.20	38.10	523.10	32.60
		556.00	32.90
		589.17	33.17
Most probable value of $\lambda = 38.262$ mm. $\pm$ 0.01, e = 0.225 mm.		Most probable value of $\lambda = 32.838$ mm. $\pm$ 0.01, e = 0.279.	

Table 1.

From the mean value of λ from table II, it would appear that the value does not vary from unity by more than one-tenth of one per cent. An unfavorable combination of errors could affect the single values by three-tenths of one per cent.

Tube A, in Steam.				Tube B, in Ice Bath.			
Exp.	λ meas.	λ cor.	T. abs.	λ meas.	λ cor.	T. abs.	$\frac{k_0}{k_{100}}$
1	38.287	38.325	370.80	32.862	32.867	272.5	1.000758
2	38.262	38.299	370.76	32.838	32.842		1.000485
3	38.303	38.339	371.12	32.860	32.864		1.000707
4	38.234	38.271	370.49	32.846	32.851		1.001770
5	38.252	38.288	370.67	32.843	32.848		1.001180
6	38.275	38.312	370.87	32.807	32.811		0.998216
7	38.231	38.268	370.84	32.863	32.869		1.003972
8	38.291	38.328	370.91	32.865	32.869		1.001020
						mean 1.001013 $\pm$ 0.000376	

Table 2.

Procedure, Series II. For the second series of measurements the procedure was substantially the same as that for the first. Carefully dried and purified nitrogen was introduced into the tubes. The upper tube surrounded by cotton and enclosed in the double walled jacket, was allowed to assume the temperature of the room, its thermometer being read through the mica windows. The lower tube, 2.2 cm. in diameter, was immersed in the liquid air bath, the top of the tube being 2 or 3 cm. below the surface. Temperatures of the liquid air were read by means of a constantan-iron thermo-junction and a sensitive millivoltmeter, which was provided with a calibration curve from the Reichsanstalt. These temperatures were checked by evaporating samples of the liquid air, mixing with hydrogen and exploding by means of an electric spark in a eudiometer tube. From percentages of oxygen thus found temperatures were interpolated from Baly's curves.[11]

[11] Phil. Mag. 49, June 1899.

Tube A, at Room Temp.

	λ
44.88	34.30
79.38	33.69
113.07	34.83
147.90	34.55
182.45	34.70
217.15	34.72
251.87	34.35
286.22	33.63
319.85	34.72
354.57	35.03
389.60	34.10
423.70	33.45
457.15	35.02
492.17	34.30
526.47	34.95
561.42	

Most probable value of
$\lambda = 34.421 \pm 0.016$,
$e = 0.44$.

Tube B, in Liquid Air.

179.12	λ
196.75	17.63
215.03	18.28
233.33	18.30
251.37	18.04
270.20	18.83
288.27	18.07
306.15	17.88
324.37	18.22
342.60	18.23
360.18	17.58
378.80	18.62
396.72	17.92
415.43	18.71
433.32	17.89
451.18	17.86
469.55	18.37
487.75	18.20
505.75	18.00
524.03	18.28
541.97	17.94
559.82	17.85
587.15	18.35

Most probable value of
$\lambda = 18.152 \pm 0.007$,
$e = 0.32$.

Table 3.

Tube A, in Liquid Air.					*Tube B, in Room Temp.*				
Exp.	Vm.	T. abs.	λ meas.	λ cor.	T. abs.	λ meas.	λ cor.	p.	$\frac{k_1}{k}$
1	7.21	83.46	18.152	18.133	293.59	34.421	34.433	72.55	1.0477
2	7.23	82.85	18.096	18.076	294.84	34.502	34.514	72.4	1.0498
3	7.285	81.18	17.938	17.917	295.24	34.555	34.572	72.1	1.0553
4	7.225	83.00	18.011	17.994	296.84	34.704	34.706	72.0	1.0336
5	7.200	83.76	18.195	18.176	296,04	34.593	34.606	72.0	1.0464
6	7.200	83.76	18.237	18.118	296.64	34.608	34.623	72.5	1.0523
								mean 1.0475 ± 0.002	

Table 4.

About five liters of liquid air were required for an experiment. The tube was left in the bath for about one hour before the glass rod was sounded. Corrections were applied for scale errors and for the expansion of the tube prior to measurement. The coefficient of expansion[12] for glass at liquid air temperature was taken as 0.0000073.

One complete set of average wave length measurements for an experiment is given in table III, and the assembled data together with the calculated values of $\frac{k_1}{k}$ are given in table IV. The subscripts relate to liquid air temperatures. All temperatures are referred to —273°.04 as the absolute zero[13].

Any change in T will alter $\frac{k_1}{k}$ inversely in about the same ratio. Temperatures were probably accurate to one-fifth of one per cent. An unfavorable combination of errors might invest $\frac{k_1}{k}$ with an error of one-half of one per cent.

From the results in table IV it would appear that k for liquid air temperature is something more than four per cent greater than for ordinary temperatures, about 22° C.

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[12] Phil. Mag. 49, June, 1899.

[13] Ann. der Physik 9, p. 1149.

Purdue University, Dec., 1910.

Investigation Concerning The Reichert-Meissl No. and the Rate of Distillation of the Volatile Acids in Butter Fat.

By George Spitzer.

In 1906 J. Delaite and J. Legrand (Bul. Soc. Chim. Belg.) investigated the determination of the volatile acid. He found the R. M. No. to increase when saponification was continued from one-fourth to six hours. This they claimed was due to depolymerization.

In the regular work of the laboratory no such variation was observed in the routine work of determining the volatile acids. The time of saponification varied from one to one and one-half hours.

To determine the effect of continuing the saponification on the per cent. of volatile acids obtained by the Reichert-Meissl process, 10 determinations were made using the same butter fat and following the A. O. A. C. method. (p. 189, 1908), the saponification being carried out under method (a), under pressure with an alcoholic solution of potassium hydrate. The saponification flasks were completely submerged in a steam bath at a temperature of 105° C. This was done to insure a more uniform temperature during the time of saponification.

The time of saponification varied from 15 minutes to two and one-half hours. The quantity of butter fat taken was as near five grams as could be weighed accurately. The result calculated on the basis of five grams.

In distilling the volatile acids the conditions were kept as uniform as it was practical, the rate of distillation being so regulated that 110 c.c., the required amount was distilled in 30 minutes.

Ten determinations were made. The results are shown in the following table.

Table I.

Showing the Effect of Time of Saponification.

Time in minutes	15	30	45	60	75	90	105	120	135	150
Reichert-Meissl No	28.32	28.25	28.35	28.29	28.29	28.28	28.35	28.32	28.28	28.31
Per cent. Vol. Acid as Butyric	4.98	4.97	4.99	4.98	4.98	4.97	4.99	4.98	4.97	4.98

Some allowance must be made in the time factor, slight saponification taking place before placing in the steam bath, also during the time of cooling after removing the flasks. But it will be observed that this factor was uniform for the 10 determinations.

From the figures in Table I. no such variations are indicated as reported.

Some of the factors which influence the Reichert-Meissl No.

Rate of distillation.

Failure to remove alcohol (when used).

Size of distilling flask.

Absorption of carbonic acid and quantity of fat taken.

All those factors are under the control of the operator and constant results are obtained by observing uniform conditions.

The rate of distillation of the volatile acid by the Reichert-Meissl process, also the rate of distillation of the volatile acids by distillation with steam.

In determining the rate of distillation of the volatile acids by the Reichert-Meissl process, the distillate was collected in fractions of 10 c.c. and titrated with $\frac{N}{10}$ NaOH.

The number of cubic centimeters of $\frac{N}{10}$ alkali required to neutralize each fraction are tabulated in Table II, also the per cent. acid calculated as butyric acid based on five grams of butter fat taken.

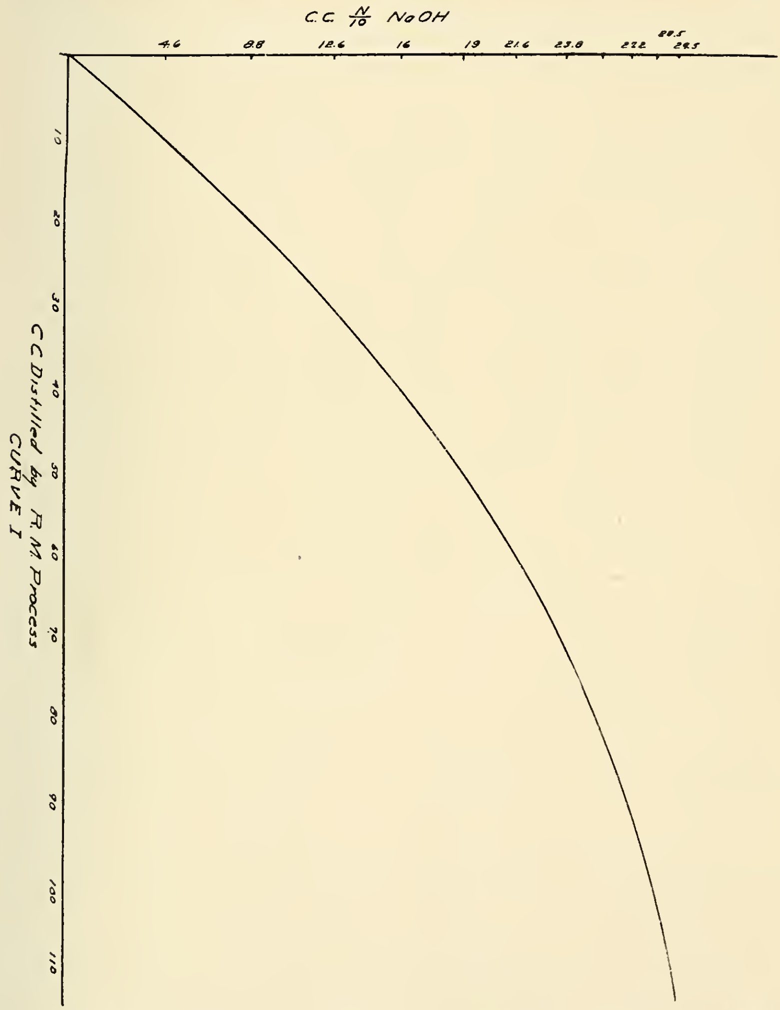
TABLE II.

Showing Rate of Distillation by the R. M. Process.

No.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Total
C. C. $\frac{N}{10}$ NaOH	4.6	4.2	3.8	3.4	3.	2.6	2.2	1.9	1.5	1.3	1.0	29.50
Per cent. vol. acid as butyric	.81	.74	.67	.60	.53	.45	.38	.35	.26	.23	.17	5.19

From Table II it will be seen that the first fraction of 10 c.c. of the distillate contains 15.6 per cent. of the total volatile acid, uniformly decreasing to the 11th fraction, which contains only three per cent. of the total volatile acid.

Plotting the above results, the volume distilled as abscissa and the number of c.c. of $\frac{N}{10}$ alkali used to neutralize the distillate, we obtain the following graphical representation of the R. M. process of distillation.



The total number of c.c. required to neutralize the volatile acid was 29.5 c.c. corresponding to 5.19 per cent. of acid calculated as butyric acid.

By the Reichert-Meissl process, we obtain only a certain fraction of the total volatile acids and which is fairly constant if carried out under standard methods.

To determine the relation of the volatile acids obtained from the R.-M. process of distillation to the total volatile acids, distillation was made with steam. By this means it is possible to estimate the total volatile acids. The usual method of saponification and precautions were taken as in the R.-M. process.

One thousand c.c. were distilled with steam and an alignment portion titrated which gave a total of 6.03 per cent. volatile acid as butyric acid. In the R. M. process, 5.19 per cent. of acid was obtained from the same butter fat. Thus we see that only 86 per cent. of the total per cent. of volatile acids were obtained by the R. M. process.

The Rate at which the Volatile Acids Distill by Means of Steam.

The same method was used as in the previous experiment in determining the total volatile acids. The distillation was collected in portions of 50 c.c. and titrated with $\frac{N}{10}$ NaOH. Twenty fractions were titrated and the result shown in Table II.

TABLE III.

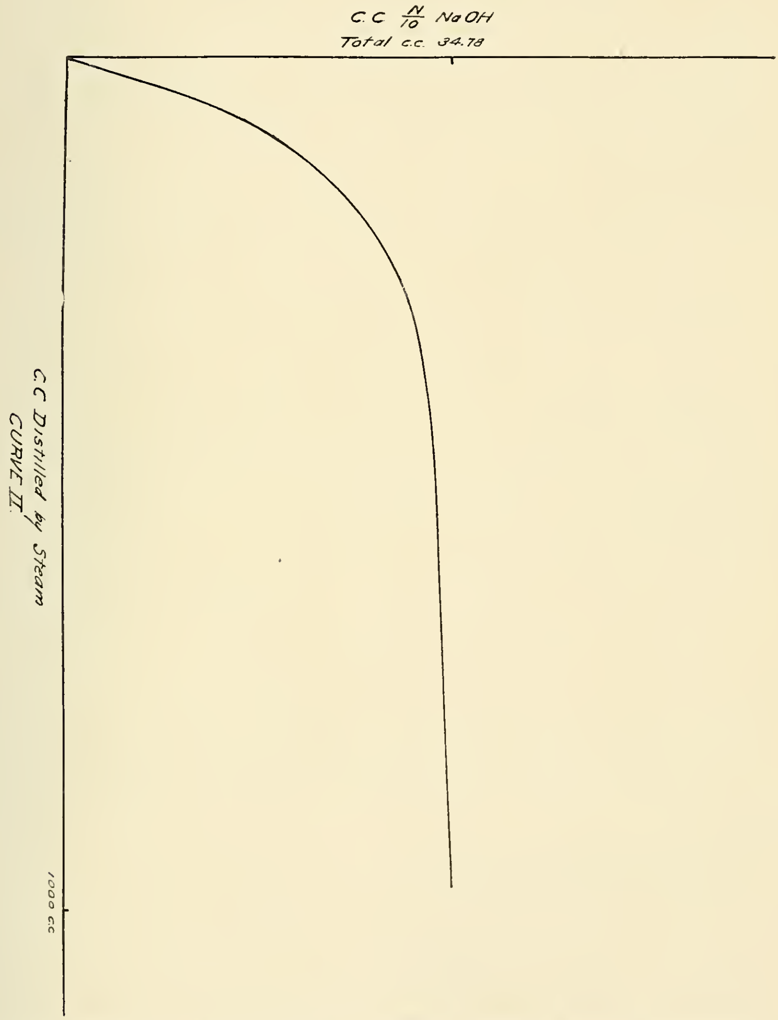
No.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
C. C. $\frac{N}{10}$ NaOH	12.7	8.48	5.58	3.66	2.4	1.52	1.00	.70	.60	.45	.30
Per cent. vol. acid as butyric	2.03	1.36	.89	.59	.39	.25	.16	.11	.08	.06	.047

No.	12.	13.	14.	15.	16.	17.	18.	19.	20.	Total
C. C. $\frac{N}{10}$ NaOH	.30	.25	.20	.20	.18	.15	.14	.13	.10	38.74
Percent. vol. acid as butyric	.047	.04	.03	.03	.028	.023	.022	.021	.017	6.22

The weight of butter fat taken for the experiment as shown in Table II was 5.50 grams. The per cent. of volatile acid and distillate is based on five grams of fat.

From Table II it is seen that the first fractions contained the greater part of the volatile acids, decreasing rapidly after the second fraction, and that the volatile acids are practically all distilled when 1000 c.c. have been collected.

Plotting the c.c. distilled as abscissa and the c.c. of $\frac{N}{10}$ alkali required to neutralize the distillate as ordinates, we get a curve quite different from the one obtained by the Reichert-Meissl process.



CURVE II.

In distillation by the R.-M. process and distillation with steam, we meet with different conditions.

In neither case is the vapor saturated with the volatile acids of butter fat during the period of distillation and the liquids in the still are made up of water and the insoluble fatty acids.

The vapor pressures of the volatile acids differ and their solubility in water and fatty acids influence the water of distillation.

Of two acids having approximately the same vapor pressure, the one which is least soluble in the mixed liquid will distill the faster.

Combining the factors, solubility in water and in the fatty acids, a mathematical expression for the rate of distillation becomes only approximately true.

Theoretically,[1] if we do not keep the volume constant as is the case in the R.-M. process of distillation, that is by making no addition to the liquid in the still during distillation,

The equation is $\frac{dy}{dx} = a \frac{y}{x}$ and integrating we get

$$\text{Log } y = a \text{ Log } x + c \text{ or } y = x^a.$$

y equals amount of volatile acids left in solution and x amount of liquid left in still, the original amount being taken as 1.

On the other hand, if the volume is kept constant as is the case in steam distillation x becomes constant.

In this case we consider the quantity of water removed to the quantity of volatile acids left in the still.

We then write equation $-\frac{dy}{dx} = ay.$ Integrating we get the equation

$$-\text{Log } y = ax + c, \text{ or } y = \frac{1}{ax}.$$

y = amount of volatile acide left in solution, original amount being taken as 1; x = amount of water and volatile acids distilled.

The above equations do not take into account the condensation in the still.

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[1] H. D. Richmond, Analyst, 1908.
S. Young, fractional distillation.

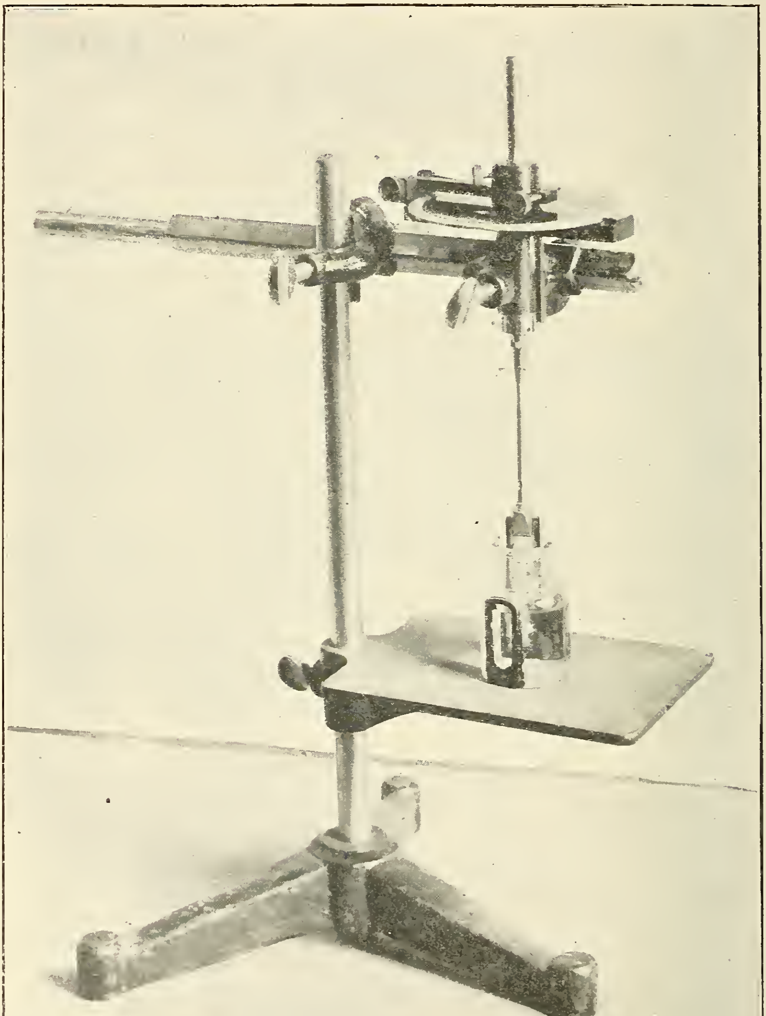
A Convenient Laboratory Device.

By J. P. Naylor.

For the last year we have been using a little device at Minshall Laboratory that has proven serviceable in so many ways that it is thought that it might be of sufficient interest to other members of the physics Section to merit bringing it before you. Used in connection with the "Universal Supports," now so common in physical laboratories, the piece is so contrived as to be adapted to a large number of experimental purposes.

The apparatus consists of a four and one-half inch circle divided to half degrees, and supported by a hollow spindle or axle. The spindle is carried by a sleeve, about three inches long, having at one end a strong crossbar. This crossbar is fitted at one end with a vernier reading on the divided circle to three minutes of arc and at the other end with a slow motion screw and clamp arranged to act upon the circle. The hole through the spindle will take a ten millimeter rod which can be clamped, by means of a screw, at any desired point. To this rod are attached the various pieces that make it possible to use the device in so many different ways. In fact, it is in the hollow spindle that the adaptability and general usefulness of the apparatus lies.

Perhaps merely mentioning a few of the purposes for which it can be used will best suggest its adaptability in laboratory or investigation work. It can be used for measuring the torsion of wires by twisting, for the torsion head of an electro-dynamometer, for measuring the indices of refraction of plane parallel plates, for measuring the angles of prisms, for making up a Kohlrausch total-reflectometer, for measuring the indices of liquids by Wallaston's method, for arranging a Wallaston's goniometer, for making up a simple polariscope or sacharimeter, as a support for measuring the angular aperture of a microscope objective or photograph lens, and for many other purposes. In fact, the apparatus can be used in a large majority of cases where the measurement of an angle is an essential part of the work. The figure shows the use of the apparatus in making up a Kohlrausch total-reflectometer.


J. P. Naylor.

Further Notes on Timothy Rust.

By A. G. Johnson.

At the last two annual meetings of the Academy, papers on timothy rust, [Puccinia poculiformis (Jacq.) Wettst.], were presented by Mr. Frank D. Kern, and it is of interest to note at this time the present known distribution of the disease over the State as well as to record here the extension of its range into other States and provinces from which it has not been previously reported.

As was predicted in Mr. Kern's papers, the distribution of the rust has become more general. In this State it evidently occurs wherever timothy is raised. During the past season the writer has collected it at widely separated points, as follows: Mount Vernon (Posey Co.) on the southwest; Wirt (Jefferson Co.) to the southeast; Richmond (Wayne Co.), east central; Columbia City (Whitley Co.), Laketon (Wabash Co.), and Logansport (Cass Co.), north central; LaFayette (Tippecanoe Co.), west central. Besides these collections, specimens of the rust have been received from Mr. Guy West Wilson and Mr. C. D. Learn, both collections from Carmel (Hamilton Co.), central; and it was reported last year from Columbus (Bartholomew Co.). This covers the State in such a way as to lead one to be reasonably certain that the rust occurs throughout the State wherever its host does.

In addition to the states and provinces from which the rust has been previously reported, specimens have been received from Dr. E. W. Olive, collected at Brookings, S. Dak., who reports it as common there this year, although not previously seen; from Miss Irma A. Uhde, collected at Lake Okoboji, Iowa; and from Prof. W. P. Fraser, Pictou, Nova Scotia. These localities in addition to those noted in Mr. Kern's paper last year make the known distribution of this rust in North America as follows. S. Dakota, Minnesota, Iowa, Wisconsin, Indiana, Ontario, New York, Maine and Nova Scotia.

In most of the specimens seen, especially those from Indiana, the summer spores (urediniospores) were much the more abundant. Winter spores (teliospores) developed in some cases but not abundantly. In certain places in Jefferson County, the rust in its uredinial stage was abundant this year. The rainy season in the southern part of the State favored the development of the fungus.

At LaFayette, on the Experiment Station farm, the uredinial stage of the rust is abundant in a timothy meadow, which was sown down this spring. The rust is most abundant in the low parts of the meadow, and even as late as at this writing (Nov. 22nd[1]) the rust sori are abundant on the green blades.

The vitality of the urediniospores, collected at LaFayette, Ind., Nov. 22nd, 1910, was tested by means of hanging drops in Van Tiegham cells. Spores were taken both from the green blades and from those that had been killed by the frost. While the former showed much the more vigorous germination, the vitality of the spores in both cases proved to be high. This shows that they have withstood the cold weather, thus far, very well, and points to the probability that the rust may be able to pass the winter here in the uredinial stage, as it is thought to do in Europe.

From the above conditions it seems evident that timothy rust is in North America to stay, and its abundance will doubtless vary with the varying conditions that favor or check its development. Some of the conditions that seem to favor the development of the fungus are a heavy, luxuriant growth of the host on ground that tends to hold moisture, along with rainy weather with cool nights and moderately still, warm, but not hot, days. Obviously, the opposite set of conditions tend to be unfavorable for the greatest development of the rust.

While the best possible attention to both air and soil drainage will no doubt lessen the attacks of the disease to some extent, yet its ultimate control doubtless lies in the field of the plant breeder. The production of a strain of timothy having a high resistance to rust, as well as having at the same time the best forage qualities, would be of vast importance.

Purdue University Agricultural Experiment Station, Lafayette, Ind.

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[1] 18 F. is the minimum thus far (Nov. 22d) at Lafayette, according to the official reading of the U. S. Weather Bureau at this station.

Indiana Fungi.

By J. M. Van Hook.

For many years fungous specimens have been collected at Indiana University and from time to time a few have been added to the herbarium. During the past four years, many more of these have been identified, while still others have been collected and determined. It occurred to the writer that a preliminary list of these might be of importance to certain members of the Indiana Academy of Science. It is our intention to add to this number as rapidly as possible, with the view of obtaining ultimately as complete a list for the State as possible. So far, previous lists have not been consulted. No species is included, which has not come under my personal observation. In a future paper, it is the writer's intention to revise and extend the list with dates of first mention in Indiana, or, the possible time and method of introduction into the State.

Practically all of the specimens have been collected in Monroe and Brown counties. The latter offers a fine field for mycological study, as some of the original forests still stand. A considerable number of specimens have been obtained in my home county—Clark. Its knobs with their deep hollows between, offer probably the best collecting ground in the State for fleshy fungi.

So far, about 1,500 specimens have been classified. These contain some 500 species distributed through approximately 175 genera. I am under obligation to Professor G. F. Atkinson, Dr. C. H. Peck and Dr. W. A. Murrill for identification or verification of some of the fleshy and woody forms.

No effort will be made to secure a long list of the rusts, as that work is already so thoroughly done by Dr. J. C. Arthur. The Myxomycetes will be studied in connection with the fungi.

In order to facilitate the work of a fungus survey of the State, we would kindly solicit specimens (especially of the Fungi Imperfecti group) accompanied with date, place of collection and host or substratum.

PHYCOMYCETES.

Albugo bliti (Biv.) O. Kuntze.
" candida (Pers.) O. Kuntze.
" ipomœa panduranæ (Schw.) Swingle.
Mucor cucurbitarum B. & C.
Phycomyces nitens (Ag.) Kze.
Plasmopara cubensis (B. & C.) Humphrey.
" viticola (B. & C.) Berl. & De Toni.
Rhizopus nigricans Ehbg.
Sporodinia grandis Link.
Synchytrium decipiens Farl.

USTILABINEÆ.

Doassansia sagittariæ (Westend.) Fisch.
Ustilago, levis Kell. & Swing.

UREDINEÆ.

Æcidium dracontii Schw.
Cæoma nitens Schw.
Gymnosporangium macropus Link.
Melampsora populina (Jacq.) Lev.
Puccinia asparagi DC.
" coronata Cda.
" graminis Pers.
" helianthi Schw.
" malvacearum Mart.
" podophylli Schw.
" sorghi Schw.
" violaceæ (Schum.) DC.
" xanthii Schw.
Uromyces appendiculatus (Pers.) Link.
" caladii (Schw.) Farl.
" euphorbiæ Cke. & Pk.
" howei Pk.
" trifolii (A. & S.) Wint.

AURICULARIINEÆ.

Auricularia auricula-judæ (L.) Schroet.

TREMELLINEÆ.

Exidia glandulosa (Bull.) Fr.
Guepinia spathularia Fr.
Tremella albida Hud.
" mycetophila Pk

THELEPHORACEÆ.

Aleurodiscus oakesii (B. & C.) Cke.
Corticium coerulium (Schrad.) Fr.
" scutellare B. & C.
Craterellus cantharellus (Schw.) Fr.
" cornucopioides (L.) Pers.
Hymenochaete ferruginea (Bull.) Mass.
Peniophora cinerea (Fr.) Cke.
Sebacina incrustans Tul.
Stereum bicolor (Pers.) Fr.
" complicatum Fr.
" fasciatum Schw.
" frustulosum Fr.
" hirsutum Fr.
" sericium Schw.
" sowerbei Mass.
" versicolor (Schw.) Fr
Thelephora palmata Fr.
" schweinitzii Pk.

CLAVARIACEÆ.

Calocera cornea Fr.

Clavaria fusiformis Pers.
" mucida Pers.
" pistillaris Linn.
" pyxidata Pers.
Sparassis crispa (Wulf.) Fr.

HYDNACEÆ.

Grandinia granulosa Fr.
Hydnum adustulum Banker.
" adustum Schw.
" arachnoideum Pk.
" caput-medusæ Bull.
" carbonarium Pk.
" combinans Pk.
" coralloides Scop.
" erinaceus Bull.
" laciniatum Leers.
" mucidum Pers.
" ochraceum Pers.
" pulcherrimum Pk.
" repandum L.
" septentrionale Fr.
" spongiosipes Pk.
" zonatum Batsch.
Irpex cinnamomeus Fr.
" obliquus Fr.
" tulipifera Schw.
Phlebia radiata Fr.
Radulum orbiculare Fr.
Tremellodon gelatinosum (Scop.) Pers.

POLYPORACEÆ.

Boletinus porosus Berk.
Boletus affinis Pk.
" alveolatus B. & C.
" auriporus Pk.
" bicolor Pk.
" castaneus Bull.
" conicus Rav.
" edulis Bull.
" felleus Bull.
" frostii Russell.
" indecisus Pk.
" luridus Schaeff.
" magnisporus Frost.
" modestus Pk.
" nigrellus Pk.
" ornatipes Pk.
" pallidus Frost.
" purpureus Fr.
" retipes B. & C.
" scaber Fr.
" separans Pk.
" speciosus Pk.
" subsanguineus Pk.
" subtomentosus L.
" subvelutipes Pk.
" vermiculosus Pk.
Dædalia ambigua Berk.
" confragosa (Bolt.) Pers.
" quercina (L.) Pers.
" unicolor Fr.
Favolus canadensis Kl.
Fistulina hepatica Fr.
Fomes applanatus (Pers.) Wallr.
" conchatus (Pers.) Fr.
" connatus (Pers.) Fr.
" fomentarius Gill.
" graveolens Cke.
" igniarius Gill.
" ribis (Fr.)
Glœoporus conchoides Mont.
Lenzites betulina (L.) Fr.
" flaccida (Bull.) Fr.
" sæpiaria Fr.
" vialis Pk.

Merulius lacrymans (Jacq.) Fr.
" rubellus Pk.
" tremellosus Schrad.
Polyporus adustus (Willd.) Fr.
" arcularius (Batsch.) Fr.
" brumalis (Pers.) Fr.
" cinnabarinus Fr.
" dryadeus Fr.
" fissus Berk.
" flavovirens Berk. & Rav.
" focicola B. & C.
" frondosus Fr.
" fumosus (Pers.) Fr.
" gilvus (Schw.) Fr.
" perennis Fr.
" perplexus Pk.
" picipes Fr.
" pilotæ Schw.
" pubescens Fr.
" radicatus Schw.
" resinosus (Schr.) Fr.
" spraguei B. & C.
" sulphureus Fr.
" unicolor Schw.
Polystictus abietinus Fr.
" biformis Klotzsch.
" cinnamomeus Sacc.
" conchifer Schw.
" hirsutus Fr.
" pergamenus Fr.
" versicolor (L.) Quel.
Strobilomyces strobilaceus (Scop.) Berk.
Trametes peckii Kalchbr.

AGARICACEÆ.

garicus campestris Schaeff.
" placomyces Pk.
Amanita cothurnata Atk.
" floccocephala Atk.
" phalloides Fr.
" rubescens Fr.
" solitaria Bull.
" strobiliformis Vittad.
" verna Bull.
Aminitopsis vaginata (Bull.) Roz.
" " " *var.* alba.
Armillaria mellea Vahl.
Cantharellus aurantiacus Fr.
" cibarius Fr.
" cinnabarinus Schw.
" infundibuliformis Fr.
" minor Pk.
" wrightii B. & C.
Claudopus nidulans (Pers.) Pk.
Clitocybe candida Bres.
" laccata Scop.
" illudens Schw.
" infundibuliformis Schaeff.
" monadelpha Morg.
" multiceps Pk.
" ochropurpurea Berk.
" odora Bull.
Clitopilus abortivus B. & C.
Collybia atratoides Pk.
" confluens Pers.
" dryophila Bull.
" maculata Alb. & Schw.
" platyphylla Fr.
" radicata Rehl.
" velutipes Curt.
Coprinus atramentarius (Bull.) Fr.
" comatus Fr.
" ebulbosus Pk.
" micaceus (Bull.) Fr.

Cortinarius alboviolaceus Pers.
" obliquus Pk.
Craterellus cantharellus (Schw.) Fr.
" cornucopioides Fr.
Crepidotus applanatus Pers.
" calolepis Fr.
" dorsalis Pk.
" mollis Schaeff.
" versutus Pk.
Entoloma griseum Pk.
" strictus Pk.
" subcostatum Atk.
Flammula betulina Pk.
Galera tenera Schaeff.
Hygrophorus ceraceus (Wulf.) Fr.
" coccineus (Schaeff.) Fr.
" conicus (Scop.) Fr.
" eburneus Bull.
" lauræ Morg.
" psittacinus (Schaeff.) Fr.
" pudorinus Fr.
" puniceus Fr.
" sordidus Pk.
Hypholoma appendiculatum Bull.
" lacrymabundum Fr.
" sublateritium Schaeff.
Inocybe fibrillosa Pk.
" geophylla (Sow.) Fr. *var.* lilacina Pk.
" rimosa (Bull.) Fr.
Lactarius chrysorrheus Fr.
" corrugis Pk.
" deceptivus Pk.
" deliciosus Fr.
" distans Pk.
" gerardii Pk.
" hygrophoroides B. & C.
" insulsus Fr.
" lignyotus Fr.
" piperatus (Scop.) Fr.
" plumbeus (Bull.) Fr.
" pyrogalus (Bull.) Fr.
" rufus (Scop.) Fr.
" scrobiculatus Fr.
" serifluus (DC.) Fr.
" sordidus Pk.
" subdulcis (Bull.) Fr.
" theiogalus (Bull.) Fr.
" trivialis Fr.
" uvidus Fr.
" vellerius Fr.
" volemus Fr.
Lentinus lepideus Fr.
" ursinus Fr.
" vulpinus Fr.
Lepiota angustana Britz.
" americana Pk.
" asperula Atk.
" cepæstipes Sow.
" granosa Morg.
" morgani Pk.
" naucinoides Pk.
" procera Scop.
" rubrotincta Pk.
Marasmius candidus (Bolt.) Fr.
" cohærens (Fr.) Bres.
" rotula Fr.
" siccus Schw.
Mycena epipterygia Scop.
" galericulata Scop.
" hæmotopa Pers.
" leajana Berk.
" leptophylla Pk.
" pura Pers.
Naucoria semiorbicularis Bull.

Nyctalis asterophora Frost.
Omphalia alboflava Moy.
" campanella Batsch.
Paneolus campanulatus L.
" retirugis Fr.
" solidipes Pk.
Panus stipticus (Bull.) Fr.
" rudis Fr.
Paxillus panuoides Fr.
Pholiota adiposa Fr.
" æruginosa Pk.
" caperata Pers.
" flammans Fr.
" marginata Batsch.
" squarrosoides Pk.
" togularis Bull.
" unicolor Vahl.
Phylloporus rhodoxanthus (Schw.) Bres.
Pleurotus applicatus Batsch.
" abscondens Pk.
" dryinus Pers.
" ostreatus Jacq.
" petaloides Bull.
" sapidus Kalchbr.
" serotinoides Pk.
" ulmarius Bull.
Pluteus cervinus Schaeff.
" leoninus Schaeff. *var.* coccineus Cke.
Russula alutacea Fr.
" basifurcata Pk.
" compacta Frost.
" crustosa Pk.
" decolorans Fr.
" densifolia Secr.
" emetica Fr.
" fœtens Fr.
" furcata (Pers.) Fr.
" granulata Pk.
" mariæ Pk.
" nigricans Fr.
" pectinatoides Pk.
" variata Banning.
" veternosa Fr.
" virescens (Schaeff.) Fr.
Schizophyllum commune Fr.
Stropharia semiglobata Batsch.
" viridula Schaeff.
Tricholoma equestre L.
" fumescens Pk.
" personatum Fr.
" russula Schaeff.
" sejunctum Sow.
Volvaria bombycina (Pers.) Fr.
" pusilla Pers.

PHALLINEÆ.

Dictyophora duplicata (Bosc.) Ed. Fisch.
" ravenelii (B. & C.) Burt.
Mutinus caninus (Huds.) Fr.

LYCOPERDINEÆ.

Calvatia cœlata Bull.
" cyathiforme (Bosc.)
" gigantea (Schaeff.) Batsch.
Lycoperdon gemmatum Batsch.
" pyriforme Schaeff.

NIDULARIINEÆ.

Crucibulum vulgare Tul.
Cyathus stercorius (Schr.) De Toni
" striatus (Huds.) Hoffm.

PLECTOBASIDIINEÆ.

Scleroderma tenerum B. & C.
" vulgare Hornem.

ASCOMYCETES.

Anthostomella ostiolata Ell.
Bulgaria inquinans (Pers.) Fr.
Chlorosplenium æruginosum (Œd.) de Not.
Cordyceps herculea (Schw.) Sacc.
" militaris (L.) Link.
Daldinia concentrica (Bolt.) Ces. & de N.
Diatrype albopruinosa (Schw.) Cke.
" stigma (Hoffm.) Fr.
" virescens (Schw.) E. & E.
Diatrypella prominens Howe.
Dichæna ferruginea (Pers.) Fr.
Dimerosporium collinsii (Schw.) Thuem.
Erysiphe cichoracearum DC.
" graminis DC.
Exoascus deformans (Berk.) Fckl.
Glœoglossum gelatinosum (Pers.) Durand.
Gibberella saubinettii (Mont.) Sacc.
Glonium simulans Gerard.
Gyromitra gigas (Krombh.) Cke.
Helotium citrinum (Hedw.) Fr.
Hypomyces lactifluorum (Schw.) Tul.
" rosellus (Alb. & Schw.) Tul.
Hypoxylon annulatum Schw.
" atropunctatum (Schw.) Cke.
" coccineum Bull.
" cohærens (Pers.) Fr.
" fuscum (Pers.) Fr.
" howeianum Pk.
" investiens (Schw.) Berk.
" petersii B. & C.
" turbinulatum Schw.
Hysteriographium gloniopsis (Ger.) E. & C.
Lachnea erinaceus Schw.
" scutellata L.
Læstadia bidwellii (Ell.) Viala & Ravaz.
Leotia lubrica (Scop.) Pers.
Microsphæra alni (DC.) Wint.
" elevata Burr.
Morchella conica Pers.
" esculenta (L.) Pers.
" semilebra DC.
Nectria cinnabarina (Tode) Fr.
" ipomoeæ Hals.
Nummularia bulliardi Tul.
" discreta (Schw.) Tul.
" tinctor (Berk.)
Otidea aurantia (Pers.) Mass.
Peziza repanda Wahl.
" succosa Berk.
" vesiculosa Bull.
Phyllachora graminis Pers.) Fckl.
Phyllactinia suffulta (Reb.) Sacc.
Plowrightia morbosa (Schw.) Sacc.
Podosphæra oxycanthe (DC.) De By.
Pseudopeziza medicaginis (Lib.) Sacc.
" trifolii (Pers.) Fckl.
Rhytisma andromadæ (Pers.) Fr.
Rosellinia aquila (Fr.) De N.
" medullaris Ces. & De N.
Sclerotinia fructigena Pers.
Scorias spongiosa (Schw.) Fr.
Sarcocypha coccinea (Jacq.) Cke.
Sphærella fragariæ (Tul.) Sacc.

Sphærographium fraxini (Pk.) Sacc.
Sphærotheca pannosa (Wallr.) Lev.
Tuber rufum Pico.
Uncinula salicis (DC.) Wint.
Urnula craterium (Schw.) Fr.
Ustulina vulgaris Tul.
Valsa leucostoma (Pers.) Fr.
Venturia pomi (Fr.) Wint.
Xylaria castorea Berk.
" hypoxylon (L.) Grev.
" polymorph (Pers.) Grev.

FUNGI IMPERFECTI.

Sphæropsidales.

Actinonema rosæ (Lib.) Fr.
Ascochyta pisi Lib.
Cicinnobolus cesatii De By.
Cytospora persicæ Schw.
Diplodia zeæ (Schw.) Lev.
Entomosporium maculatum (Cke.) Sacc.
Darluca filum (Biv.) Cast.
Leptothyrium pomi (Mont. & Fr.) Sacc.
Phoma polygramma (Fr.) Sacc. *var.* Plantaginis. Sacc.
Phyllosticta ampelopsidis Ell. & Mart.
" prunicola (Op.) Sacc.
Septoria graminum Desm.
" lycopersici Speg.
" piricola Desmz.
" podophyllina Pk.
" rubi West.
" trillii Pk.
Sphæronema fimbriatum (Ell. & Hals.) Sacc.
Sphæropsis grandinea E. & E.
" malorum Berk.
Vermicularia circinans Berk.

Melanconiales.

Colletotrichum lindemuthianum (Sacc. & Magn.) Bri. & Cav.
Cylindrosporium padi Karst.
Marsonia brunneum E. & E.
" ochroleuca B. & C.

Hyphomycetes.

Acrostalagmus cinnabarinus (Pers.) Cda.
Alternaria brassicæ (Berk.) Sacc. *var.* macrospora. Sacc.
" solani (E. & M.) Jones & Grant.
Botrytis vulgaris Fr.
Cephalothecium roseum Cda.
Cercospora apii Fres.
" beticola Sacc.
" condensata Ell. & Kell.
" viticola (Ces.) Sacc.
Cladosporium carpophilum Thuem.
Fumago vagans Pers.
Helminthosporium carpophilum Lev.
" inconspicuum C. & Ell.
Piricularia grisea (Cke.) Sacc.
Polythrincium trifolii B. & C.
Streptothrix atra B. & C.
Stysanus stemonites (Pers.) Cda.
Tubercularia vulgaris Tode.
Zygodesmus fulvus Sacc.

Indiana University,
Bloomington, Ind.

Steccherinum Septentrionale (Fr.) Banker in Indiana.

By Howard J. Banker.

The fungus here considered is perhaps better known as *Hydnum septentrionale* (Fr.). Although a large and conspicuous plant it appears to have attracted very little attention if we are to judge by the references to it in literature. In the entire series of Just's Botanischer Jahrsbericht covering a period of more than twenty years I did not find a single reference to this species. As to size it possesses the unique distinction of being by far the largest representative of the family of the Hydnaceæ, if not indeed being able to lay claim to the first place in this respect in the entire fungal world. A specimen that recently came under the writer's observation and which is the occasion of this paper, after being damaged and a portion of it lost, weighed 35 lbs. The whole mass measured 30 cm. long, or in its projection from the substratum, 58. cm. wide, and 40. cm high. I should not be surprised if specimens were to be found considerably exceeding this in size.

The formation of the sporophore is somewhat peculiar. The mycelium emerges from the main trunk of the tree through some small opening such as the hole formed by a dead limb. In the case of the plant here shown it emerged under the base of the tree in a crevice formed by the divergence of buttress-like roots and where there was a small opening apparently into the heart of the tree. In every case that I have observed, the opening has not been over ten centimeters in diameter and is out of all proportion to the size of the sporophore. On emerging from the hole the mycelium apparently grows radially, spreading in close adhesion to the substratum and forming outwardly a series of overlapping or imbricate pilei. The first impression is that the mass is thoroughly rooted in the tree at all points and can be removed only by breaking it in pieces or by cutting out a portion of the tree. However, it will be found that no stronger implements than one's fingers are sufficient to remove the specimen intact, for its attachment to the bark is very slight and the fingers can easily be forced between the fungus and the tree, pushing it off until the small cord of mycelium which forms the real point of attachment is broken.

Steccherinum septentrionale, growing from crevice near base of living beech at Greencastle, Ind.
Photograph by Paul Collins, magnified one-fifth.

For weeks after the removal of the fungus the spot on the tree where it had been can be detected by its lighter color, looking as if it had been cleaned. There are, however, no other external marks of the effect of the fungus and the tree appears to suffer little vital injury. Some six years ago a fine specimen was found growing on a beech at a height of 12 or 15 feet from the ground in the dooryard of Dr. Edwin Post in Greencastle. The tree is still living and apparently thriving. The top of the tree has been cut off or broken out, apparently many years ago and certainly prior to infection by the fungus. The plant does not seem to kill the tree, but such a fungal mass could hardly be produced without considerable injury. The fungus has been observed only on large trees a foot or more in diameter. The writer has not been able to examine the wood of a tree attacked by the fungus, but it seems probable that the mycelium may be confined to the heart wood, which would account for the little injury done to the growing tree, as well as the fact of its confinement to old trees.

It seems probable also that the sporophores are produced from small openings, because these offer a suitable path of exit through the sap-wood. It may appear, therefore, strange to speak of the plant as a parasite; but while its mycelium may be confined in its vegetative state to the non-living heart-wood, it is also true that the fungus appears to be confined to living trees and is never found on dead trunks, whether standing or fallen.

The plant seems to prefer the beech as its host. It has been reported as growing on maple and perhaps hickory in the East, where beech is not very abundant. I have never seen the plant *in situ* on the latter hosts, and illustrations suggest the possibility of the plant's being more or less distinct in character from the one found on beech. The original description and figure by Fries was from specimens found on beech in Sweden. These are in every respect typical of specimens found here in Indiana. I have seen no entire specimens of the European form on beech. At Upsala there is in the herbarium an entire specimen of extraordinary size that was found growing on Linden in the Botanical Garden of the University. Although the specimen is dried, it is evident at sight that the plant presents some striking differences from our Indiana plants. The pilei are much smaller, thinner, more numerous and more distinct, the color cinereous rather than creameus, and the teeth somewhat shorter. It is only after closer examination that one hesitates to pronounce it a distinct species. Fries makes mention of the plant's being found on elm in the same Botanical Garden, and names a variety, *hortense*, found on the latter host. So far as I know, the plant has never been observed in this country either on linden or elm. It is possible that the influence of the host may affect somewhat the growth of the plant, if these are all one species. This is a point that needs further investigation.

The immense sporophore is a single season's growth and it seems probable is produced very rapidly in the course of a few weeks in August and September, reaching maturity about the first of October. The form found on maple in the east has been observed to fruit several years in succession, and Fries speaks of the plant as growing annually on elm at Upsala. The beech in Dr. Post's yard two years later produced a small fungal growth, but too high up to be sure of its character, since which time no further growth has been observed. The tree on which the present growth was found gave no indications of any previous growths. Other observations lead me to believe that it is not usual for the beech fungus to fruit annually for a series of years. How long the mycelium lives in the tree is unknown.

The spores are produced in enormous numbers, but seemingly for only a few days. On my first visit to this plant, October 17, no spore fall was observed, but the matter was not especially tested. Two days later, on visiting the place, spores were observed rising from the mass in small clouds. These frequently streamed out from parts of the fungus like a puff of smoke for 10 or 15 seconds, then ceased and after two or three minutes began again. Such streams were emitted from different parts of the plant irregularly, so that from some part spores were escaping almost constantly. The day was pleasant and the air very quiet, yet occasionally a light puff of air passed over the plant. The streaming of the spores, however, appeared to be no more marked when the air stirred than when it was perfectly quiet. The plant was carefully removed from the tree, but being found too heavy to carry was left propped against the base where it had grown. Five days later the fungus was brought to the laboratory and found to be in good condition, but the outer edges of the pilei were beginning to darken and curl. Faint spore prints were obtained, but such as to indicate that spore discharge was practically over. Whether the removal of the plant from the tree shortened the time of spore discharge is not certain, but it is doubtful if the plant gives off its spores naturally for a period of more than a week or ten days.

According to Buller, visible spore-discharge in the hymenomycetes is a rare phenomenon, and he cites the observations of Hoffman, Hammer, and von Schrenk. My own observation on *Steccherinum septentrionale* conform to Von Schrenk's description of the spore-discharge in *Polyporus schweinitzii.* Buller accounts for the intermittent clouds by tiny irregular air currents, and thinks the spores were in reality "falling continuously and regularly by their own weight." In the case of his own observation on *Polyporus squomosus* this view appears to be confirmed, and he likens the appearance to the steam arising from a cup of tea in irregular eddies or the curling of tobacco smoke from the bowl of a pipe. Had he observed the discharge in *Steccherinum septentrionale* I believe he would not have felt so confident of his explanation. The cloud-like discharge was more as the curling smoke of the tobacco when one breathes at intervals through the pipe. I doubt if the discharge is due to any propelling force as hinted by Von Schrenk, but it seems to me probable that over certain restricted areas there is a simultaneous liberation of great quantities of spores followed by a period of rest. That such intermittent spore release occurs in all hymenomycetes is improbable, but it seems to account for the phenomenon as observed in *Steccherinum septentrionale* and *Polyporus schweinitzii.*

Whether the present fungus is to be regarded as an edible species can not be stated. No one appears to have tested its qualities. It would probably be found somewhat tough, especially when mature, but not more so than many forms that are recommended. In drying it gives off a very strong odor which would lead one to expect it to have a pronounced flavor. The taste of the raw plant is not inviting, and yet not particularly offensive. If any preparation of it would make it really comestible, a single plant is sufficient to furnish an abundant feast.

The plant is not rare and yet cannot be said to be common. It appears to be most abundant in Indiana and Ohio, perhaps because of the prevalence of the beech in this region. When the writer came to Indiana six years ago, he had not been in the State more than a couple of weeks when his attention was called by one of his students to the specimen previously mentioned in Dr. Post's yard. As there were three or four dried specimens observed lying about the laboratory, the impression was given that specimens could probably be readily obtained almost any time in season. Being at the time unusually busy organizing a new work, the opportunity for study of the plant was allowed to pass with a casual examination and the securing of the specimen. From that time until this fall, however, no more were seen except one or two old and badly weathered specimens. The plant is, therefore, not so abundant as was thought. Press of other work has again made it impossible to conduct as thorough an investigation of the problems suggested by this plant as one would like, but it has appeared worth while to call attention to this seemingly little noticed fungus.

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Disease Resistance in Varieties of Potatoes.

By C. R. Orton.

This report is the result of experiments conducted by the author, under the direction of Dr. L. R. Jones, while in the coöperative employ of the Vermont Experiment Station and the United States Department of Agriculture, Bureau of Plant Industry, during the fall of 1909-10.[1] In general, the work was the outgrowth of a series of experiments carried on by Professor William Stuart at the Vermont Station for several years previous to 1909, the results of which may be found in Bulletin 122, Vermont Experiment Station. In particular, it was the development of some research work of the previous winter on late blight. Professor Stuart conducted his experiments in the field upon over 150 varieties, with the idea of determining, if possible, the disease resistant qualities of both American and European varieties of potatoes, to the late blight, *Phytophthora infestans* (Mont) Bary, a fungus which causes the loss of many thousands of bushels of potatoes yearly in New England, especially in Maine and Vermont, and periodically the loss of one-half the entire crop or more in that section.

European potato growers have for years been breeding and testing potato varieties for the disease resistant quality, until they have developed a series of varieties which have proved by field trials to be highly resistant to fungous diseases. The processes as carried out by them necessitated growing the tubers for several years in succession and noting the amount of infection each year. This, of course, is at best a tedious operation, giving slow and often unsatisfactory results.

In 1908 Mr. N. J. Giddings, then of the Vermont Experiment Station, found that resistance to the late blight could be determined with some degree of accuracy by artificial inoculation of the tubers, with pure cultures of the fungus, under sterile conditions in the laboratory. The value of the laboratory method for testing varieties of potatoes for disease resistance is easily seen when we consider that it would permit us in two or three weeks to test the resistance quality of any variety, a process which

[1] The full results of these experiments are to be published in a forthcoming bulletin of the United States Department of Agriculture, Bureau of Plant Industry.

heretofore by laborious field experiments has taken as many years. The purpose in the trials of 1909 was to determine more fully the reliability of this method and its applicability for comparative trials with a large number of varieties.

In all, 76 varieties of potatoes, 46 of which Dr. Jones collected in Europe, were tested. Practically all of these were varieties of economic value in their respective localities. Most of the European varieties were of reputed disease resistant qualities. All had been grown on the Vermont Experiment Station grounds under as similar conditions as possible, for four years previous to these experiments.

The method used was, first, to prepare sterile test tubes by placing a small absorbent cotton wad in the bottom of each tube and adding to each one c.c. of water. The tubes were then plugged with ordinary cotton and sterilized in the autoclave. The next step was to place in each such tube a small sterile block cut from a raw potato. Considerable care was necessary to avoid contamination in this process. The work was all done under a transfer hood freshly washed out with corrosive sublimate solution. The potato tubers were first washed then immersed for about five minutes in a corrosive sublimate bath. They were then peeled with sterile knives and the sterile interior flesh was finally cut into several small blocks of such size, about 1 x 1 x 4½ cm., as would drop easily into the tubes. These tubes were then held 24 hours at about 22° C., in order that any contaminated tubers might be detected and discarded before the inoculations were made. The inoculations were made from pure cultures of *Phytophthora infestans* growing on lima bean agar and about 15 to 18 tubes of each variety were inoculated. About twelve varieties were run in each series, two of these varieties used as checks, being the same in all the series. For these checks Professor Wohltmann and Green Mountain varieties were used because they showed a very uniform growth all through and stood at the two extremes, the former being one of the most resistant varieties, the latter one of the most susceptible.

For each inoculation, a small piece of the fungus was transferred with a platinum needle from the agar to the block of potato and scratched into it to prevent its drying up before infection could take place. If proper care was taken in making this inoculation, a uniform growth was obtained on all the blocks of the same variety.

After inoculation the cultures were placed for incubation and growth in a temperature of about 15° to 16° C. It was found that at this temperature they developed a fair growth of the fungus in about six days, and this reached a maximum on about the tenth day. All the tubes of each variety were then assembled and compared with the checks as to their relative amounts of growth. These results were judged by two or three observers independently of each other, and each judgment recorded. For purposes of comparison the relative growth was expressed in percentages. Although this was a somewhat arbitrary standard its usefulness is shown by the fact that these independent observations rarely varied more than five to ten per cent.

For the final results all these tests were made in duplicate and all the observations on any one variety were averaged. These averages may be grouped into three main classes. First, a highly resistant class, those exhibiting a growth of from 1-35 per cent. Second, a middle class, those exhibiting a growth of from 35-66 per cent, and third, a susceptible class, exhibiting a growth of from 65-100 per cent. It was found that those falling into class one were in every case those which were of tested disease-resistance and were practically all of European origin. Those falling into class two were largely of reputed disease-resistance and were also largely of European origin. Those falling into the third class were practically all of American origin and included many of our most important commercial varieties. Since these results, in the main, correspond to those obtained by Professor Stuart, in his field trials, we feel safe in drawing the conclusion, that thus far our American breeders of potato varieties have been developing types which stand for yield and quality regardless of disease-resistance, while European breeders have been developing disease resistant varieties. This, we believe, explains in a measure, the heavy loss occasioned by fungous disease in our American potato crop. Unfortunately the most resistant of the European varieties are not of the best quality and color for the American market. It therefore remains for the potato breeders of this country to develop varieties which combine the desirable qualities of the best American potatoes with the disease-resistant qualities of the hardiest European potatoes. In connection with this it will undoubtedly be the laboratory method here explained which will be used largely in testing the disease resistant qualities of new hybrids and seedlings in the attempts to develop this new ideal potato.

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An Ecological Survey of Whitewater Gorge.

By L. C. Petry and M. S. Markle.

At Richmond, Indiana, the east branch of Whitewater River runs through a narrow rock gorge for a distance of about three miles. This miniature canyon is commonly called the Whitewater gorge. It varies in

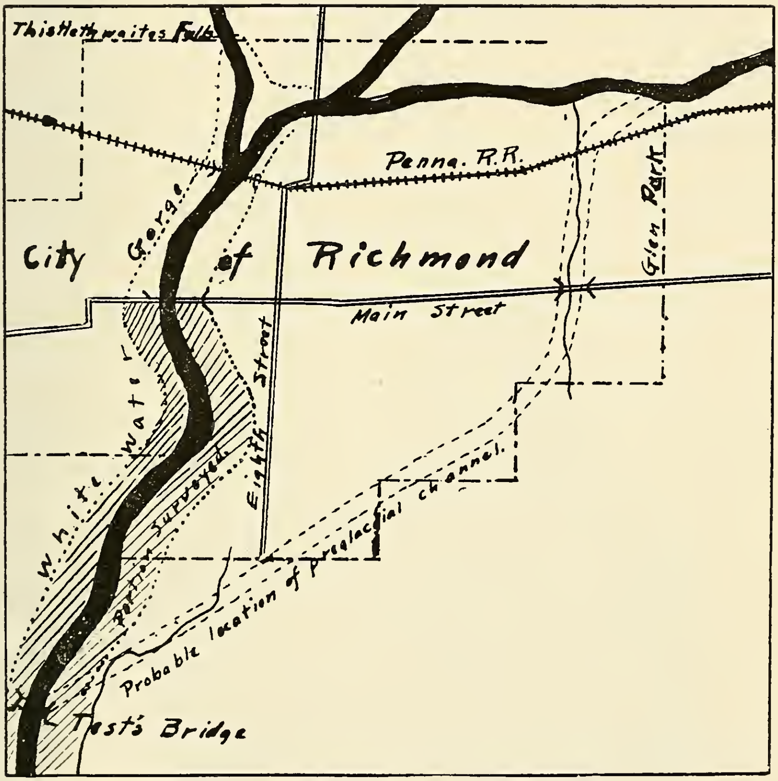


Fig. 1.

depth from 60 ft. to 120 ft. and in width from 200 ft. to 800 ft. on the floor. The gorge terminates rather abruptly at Test's Mills, about two miles below Main street, Richmond, and from that point to its mouth the valley is generally broad.

This gorge was formed as a direct result of the glacial phenomena of the region. There is evidence that at the close of the Early Wisconsin ice sheet period, the river occupied a channel much to the eastward of its present course. Wells to the south of Glen Park, nearly three miles east of the present river channel indicate at that point an old channel now filled with drift. The streams in Glen Park seem to occupy this same old channel. From this and other evidence it seems probable that this old channel passes to the east of the city of Richmond, and connects with the present river valley somewhere below Test's Mills.

The advance of the Late Wisconsin ice sheet resulted in filling up this old channel with drift. There is evidence that this ice advance was from two directions, north-west and north-east, and that the terminal moraines of the two lobes did not come together. The river, forced out of its old channel, took up a new course between the two moraines. With the melting of the ice sheet, the volume of water discharged by the stream would be very large, and erosion of its channel correspondingly rapid. Since the retreat of the ice, it has carved the present gorge.

The rock of the gorge is Hudson River or Cincinnati limestone. This is a favorite collecting ground for paleontologists interested in this particular portion of the Lower Silurian beds. Trilobites are not numerous, though several species are found. Calymene senaria is commonest. Rynchotrema capax, Zygospira modesta, Platystrophia biforata and Leptæna rhomboidalis are the characteristic brachiopods. Streptolasma is extremely common.

The character of the rock is of extreme importance in the consideration of the ecology of the region. The rock is soft and very thin-bedded, and is rendered still more unstable by the alternation of thin beds of shale of a soft calcareous nature with the layers of limestone. The limestone itself is shaly and weathers very rapidly. Three inches is probably the average thickness of the rock layers. The amount of shale varies greatly, even within limited areas. In general, the shale makes up about one third of the total rock.

As a result of the nature of the rock, steep cliffs are maintained only where active erosion of the base is going on. As soon as river erosion ceases, the slope becomes gentler at once. There is a considerable amount

Fig. 2.
An early stage in plant succession.

of seepage and slumping is frequent. A large talus quickly collects. This is composed of angular fragments of the limestone, embedded in a matrix of the fine mud produced by the weathering of the shale.

The stream through the gorge has a very high gradient. From Main street to Test's Mills, a distance of about 9,000 feet, the total fall is 47 feet, or about 1 foot in 200. This gradient is not at all uniform throughout the distance. In general the stream consists of a series of alternate ponded stretches and rapids. At some of the fall lines a difference of level of six or eight feet may occur. This condiition is produced by a slight dip of the rock strata toward the up-stream end of the gorge. This dip is small, not more than a few inches to the hundred feet. Where a portion of the rock, harder than the surrounding rock or with less shale, comes to the surface, a fall line is produced. Fragments of rock carried down by spring floods accumulate at this point, and the portion of the stream immediately above becomes ponded. Some of these ponds are as much as 1,200 feet in length.

The annual rainfall in this region is about 40 inches. The average flow of the river is about 60 cubic feet per second. A series of measurements of the flow, made January–May, 1907, gave a minimum flow of 56 cu. ft. per second on February 20, and a maximum flood stage of 4,500 cu. ft. per second on March 13. Measurements made in August, 1908, indicated a flow of only 42 cu. ft. per second.

It is a deplorable fact that up to the present time the city of Richmond has seen fit to dispose of its sewage by the primitive method of dumping it directly into the river. Since this sewage flow amounts to 12 to 15 cubic feet per second, or one-fourth the total flow at low water stage, the condition of the river below the sewers may be imagined.

The region selected for study includes the floor and bluffs of the gorge between the Main street bridge and the bridge at Test's Mills, about two miles to the south. A survey by transit and stadia was made and from this a topographic map on a scale of 1 inch to 250 feet was prepared. On this the various data were recorded, and the conditions of the various portions of the area were indicated by tints. Considerable areas of the region have been disturbed by cultivation, building operations, etc., and no attempt to study these areas was made. Photographs to show the more striking features of the region were made whenever possible. The nomenclature used is that of Gray's Manual, 7th edition.

Fig. 3.

A slightly later stage than that shown in Fig. 2. Note shelf plants and texture of rock.

In this study, the various plant associations have been considered as members of a succession, and therefore, in general, transitional. The ultimate stage in this region, *i .e.*, the permanent association, is held to be a very mesophytic forest, dominated by Fagus and Acer saccharum. All other plant associations are held to be transitional stages between a plantless condition and this ultimate forest condition. The position of any given plant association in this succession may be determined accurately only by observation over a long period of time. The successive stages have been worked out carefully in many cases, however, and the usual succession for this region is well known. Two kinds of successions are recognized, namely, biogenic and physiogenic. A biogenic succession may be defined as one influenced only by plant and animal life, and therefore such a succession will occur only where the physiography is static. In physiogenic successions, physiographic changes are the controlling factors. In general we have endeavored to determine two points with regard to each plant association, namely, its place in the succession and whether the controlling factors of that succession at that stage are biogenic or physiogenic. Lists of species given are usually incomplete but as representative as possible.

The walls of the gorge and the ravine branching from it are quite favorable for the study of plant successions in such situations. Within the region studied, almost all stages from the bare plantless cliff to the ultimate mesophytic forest can be found. The stage of development of the vegetation on the walls of the gorge seems to be dependent largely upon the length of time that has elapsed since active erosion by the river ceased. The succession is very rapid for a rock cliff. This is explained by the very unstable nature of the rock, the abundance of shale and the favorable conditions of rainfall and climate. Very often stages that are usually successive occur combined, or telescoped, here. Lichens, which usually form the first vegetation on rock cliffs, are absent. No liverworts or ferns occur. The oaks, which commonly form a stage immediately preceding the ultimate forest, seem to be replaced by elms and black locust. Juniperus is the only conifer found.

The earliest stage of the succession occurs at one point where a cliff occupies the outside of a curve of the stream, and active erosion of its foot is going on. As a result of this condition, the cliff is very steep, even overhanging to a slight extent. The wall is bare of plants, except for algae

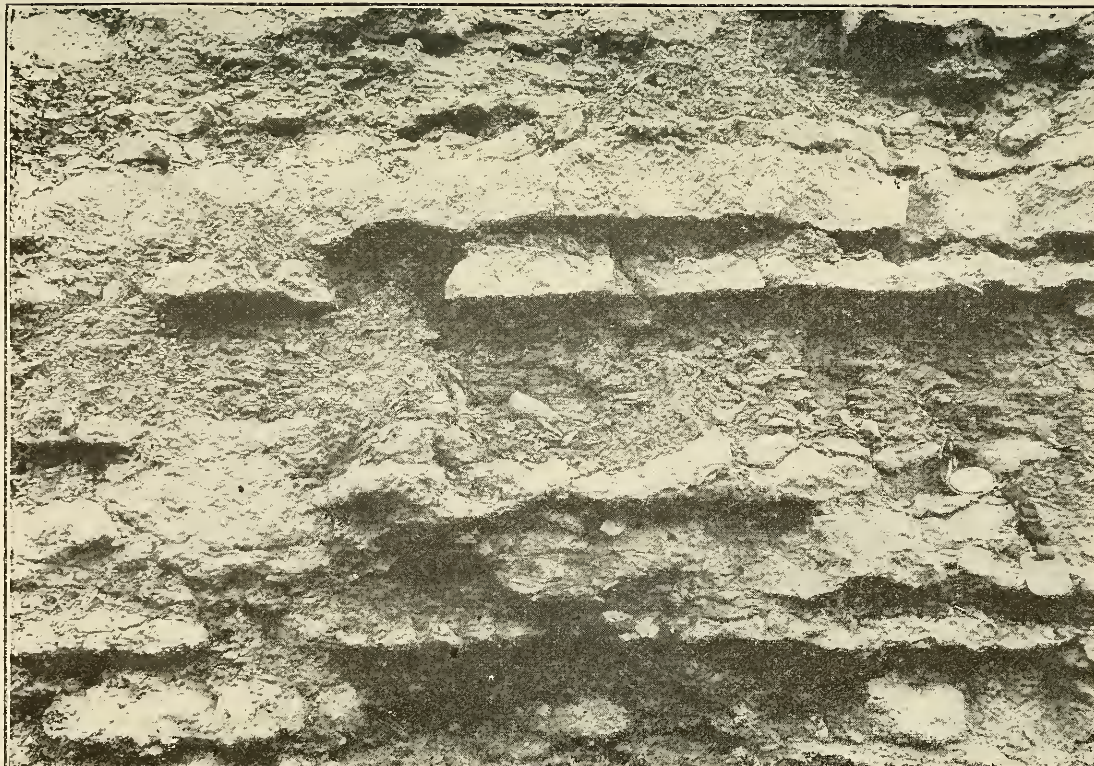


Fig. 4.

Detail of Fig. 3 showing character of rock in gorge. Note alternate layers of limestone and shale.

in places where seepage occurs. No lichens occur, though the rock is more stable than usual, with a smaller proportion of shale. Their absence is not due to smoke, as is sometimes the case, for they occur on trees near by. The rock does not contain bitumen which sometimes prevents their growth, notably on Niagara limestone. It seems probable that the weathering of the rock is too rapid for them to maintain a foothold. A few annuals grow on the talus which has accumulated since the spring floods. A few plants, such as Psedera, Rhus toxicodendron, Vitis and Juniperus virginiana, hang from the top of the cliff. This stage continues as long as active erosion by the stream is maintained.

The second stage is found at a point where the river erosion is not so strong. A considerable talus accumulates at the base of the cliff, and this is not swept away by the spring floods. The wall is not so steep as in the stage just described. It is in this stage that the first real plant associations appear. These pioneer plants occupy narrow shelves produced by the projecting ledges of limestone. Most of the plants are annuals. The following species are typical of such localities:

Ambrosia artemisiaefolia	Melilotus alba
Poa compressa	Allium canadense
Lactuca scariola var. integrata	Dipsacus sylvestris
Nepeta cataria	Aster spp.
Rosa humilis	

After direct action by the river has ceased, the talus accumulates undisturbed. The shale layers change to soil very readily, and this is washed down by the rains. Projecting layers of limestone break off of their own weight. In these various ways, the slope is rapidly reduced. A larger number of plants gain a foothold and the cliff is covered with vegetation. Grasses and annuals are common. Xerophytic mosses appear. This may be called the herb stage. The pioneer plants mentioned above continue through this stage, while the following new species appear:

Equisetum arvense	Melilotus officinalis
Aster novæ-angeliæ	Cornus paniculata
Daucus carota	Verbascum thapsus
Heracleum lanatum	Elymus canadensis

Up to this point, the succession has been almost entirely physiogenic. The plantless stage continues as long as the stream actively erodes the

Fig. 5.

A ponded portion of the stream.

base of the cliff. After this erosion ceases, the plant succession is determined for a time by the slope of the cliff. At first, only shelf plants can gain a foothold. As the slope is reduced, the number of species is increased. After a time, though, when a soil of considerable depth has formed, the succession becomes biogenic. The plants hold the soil, and the reduction of slope proceeds very slowly, if at all, particularly after grasses become prominent. The slope of the gorge wall where it is covered with a mesophytic forest is but little gentler than that of the wall where only bushes occur. From the herb stage to the ultimate mesophytic forest, each plant stage prepares the way for the next in the succession by holding the soil, accumulating humus and furnishing shade.

The herb stage is succeeded by a bush stage. The most prominent species is Rhus canadensis, which often forms large colonies. Cornus paniculata and Salix longifolia are commonly associated with it. Rubus, Ribes, Rhus toxicodendron, Vitis vulpina, Cratægus, Psedera, Ptelea trifoliata and others occur, together with a number of species characteristic of the preceding stage, such as Dipsacus sylvestris, Heracleum lanatum, etc.

This shrub stage is probably very brief and pioneer trees soon appear. Two parallel tree stages appear. Considerable areas are found occupied by Ulmus americana, Celtis occidentalis and Cratægus spp. In other situations similar in all respects, Cersis canadensis, Robinia pseudo-acacia and Prunus americana dominate the vegetation. In both cases, the trees are accompanied by a large number of undergrowth herbs and shrubs, among them the following:

Gleditsia triacanthos	Heracleum lanatum
Juglans nigra	Daucus carota
Cornus paniculata	Taraxacum officinale
Sambucus canadensis	Aster spp.
Ribes cynosbati	Verbascum thapsus
Vitis vulpina	Nepeta cataria
Psedera quinquefolia	Poa compressa
Menispermum canadense	Solanum nigrum
Dipsacus sylvestris	

Following these two parallel stages appears the ultimate stage of the region, the mesophytic forest. This stage occurs only on the east bluff of the gorge, immediately above Test's Mills. That this forest is really

Fig. 6.

Border plants along ponded portion of stream.

mesophytic is shown by the presence of Fagus grandifolia and Acer saccharum, the latter being very abundant. This forest is rather open yand this probably accounts for the absence of all ferns. Polypodium is found in similar locations in this region, however. Mosses are abundant on the ground and on fallen logs. The only liverwort is Porella, occurring abundantly on tree trunks near the ground.

In order to establish the fact that the forest represents the ultimate stage of the succession for this region, a primeval mesophytic forest near Williamsburg, Ind., about ten miles distant, was studied and a list of the species found there is given below. On this list, those species marked by an asterisk occurred also in the forest on the east bluff of the gorge at Test's Mills. A study of the list will lead to the conclusion that the ultimate stage of the succession has been reached here:

*Carpinus caroliniana
*Fraxinus americana
*Fagus grandifolia
*Aesculus glabra
*Ostrya virginiana
*Cornus florida
*Acer saccharum
*Carya cordiformis
*Ulmus racemosa
*Asimina triloba
*Morus rubra
*Smilax hispida
*Psedera quinquefolia
*Ribes cynosbati
*Juniperus communis
*Vitis vulpina
*Rosa setigera
Benzoin æstivale
*Rhus toxicodendron
Celastrus scandens
*Menispermum canadense
*Viburnum prunifolium
*Sambucus canadensis
Mitchella repens
*Carya ovata
*Ulmus americana
*Ulmus fulva
*Tilia americana
*Quercus alba
*Fraxinus quadrangulata
*Celtis occidentalis
*Quercus rubra
Aralia nudicaulis
*Urtica gracilis
Polygonum virginianum
*Bidens frondosa
Monotropa uniflora
Epifagus virginiana
Smilacina racemosa
Boehmeria cylindrica
*Aristolochis serpentaria
Sanguinaria canadensis
*Solanum nigrum
Polygonatum commutatum
Cryptotænia canadensis
Actæa spicata
Viola pubescens
Monarda fistulosa

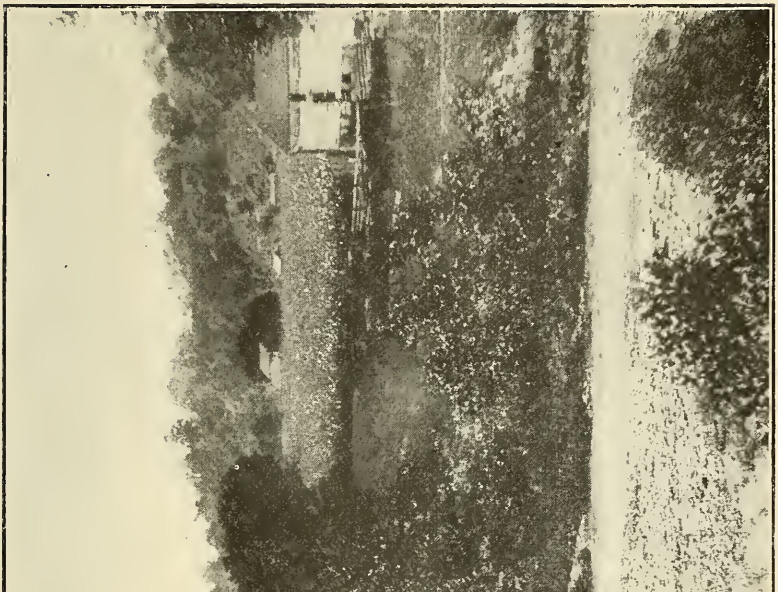


Fig. 7.
A Xerophytic Floodplain.

Hydrangea arborescens	Hepatica acutiloba
*Eupatorium urticæfolium	Arisæma triphyllum
*Impatiens biflora	Botrychium virginianum
Impatiens pallida	Botrychium ternatum
*Galium spp.	Adiantum pedatum
*Viola cucullata	Polystichum acrostichoides
Aralia racemosa	Asplenium augustifolium

In addition to the species indicated by asterisks, Quercus prinus and Sedum ternatum are prominent members of the vegetation of this stage of the bluffs.

Several narrow terraces occur along the sides of the gorge at various points. They vary in width from a few feet to as much as 200 feet, and one of these, on the east side of the river near the bridge at Test's Mills, is about half a mile in length. The origin of these was not investigated.

Rejuvenescence, that is, a return to pioneer conditions, may occur at any stage of the succession, if erosion of the base of the cliff is resumed by the river. In this case, the undercutting by the stream produces slumping, and the bare rock wall is soon exposed. This condition occurs at the foot of the east bluff, just below the small islands at the lower fall line. At this point the bluff had become mesophytic before erosion of the foot began again. We have here at the present time an extremely xerophytic bare rock face bordering directly upon a mesophytic forest. This xerophytic condition will continue as long as the stream erosion continues, and its area may even increase. When erosion ceases, the succession will begin again, and progress through the stages just described.

The ravines entering the gorge are small and comparatively few in number. The fact that the gorge is relatively young explains this in part. The smallness of the area draining into the gorge at this point is probably the principal factor, however. Clear Creek parallels the river on the west, and the divide between the two streams is less than half a mile west of the river. On the east, another small stream parallels the gorge at an even less distance. Accordingly the drainage of the area immediately around the gorge is largely accomplished by parallel streams which enter the river farther down. With two exceptions, the ravines are less than 200 yards in length, and are accordingly very steep. These two ravines have permanent streams, fed by springs. In the others, the rocks drip with seepage, but streams run through them only after rains.

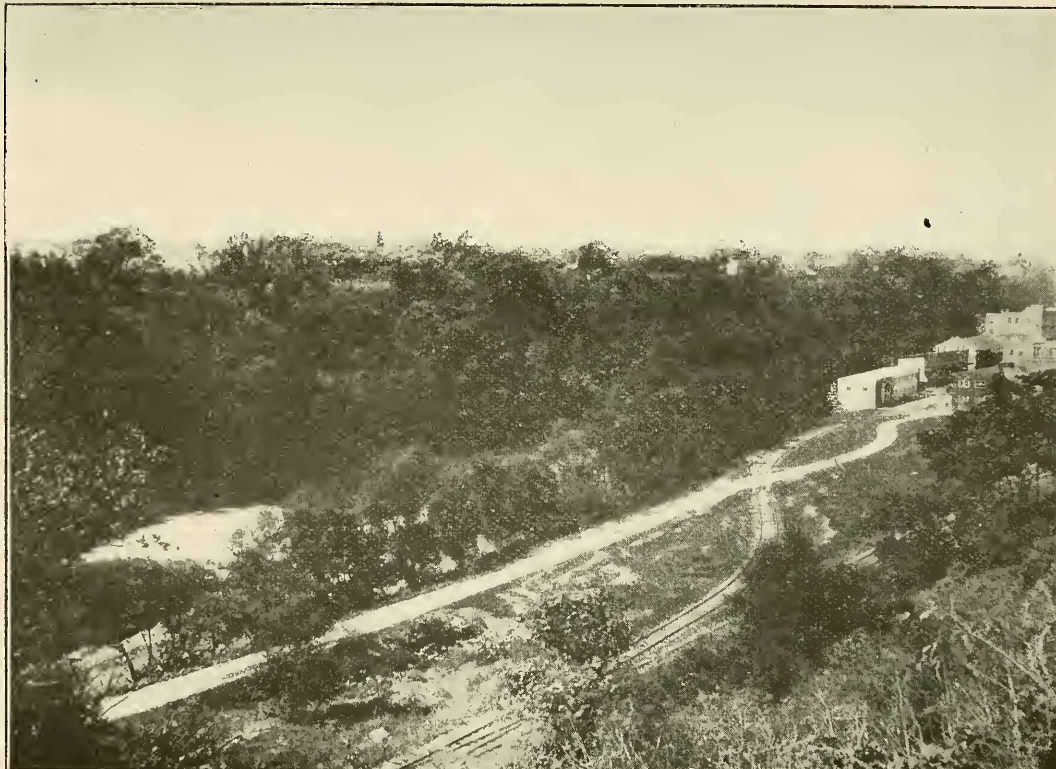


Fig. 8.

View across Gorge. Note nearly mesophytic forest on opposite bluff and border of Salix nigra.

All stages from young ravines. with conditions extremely xerophytic up to mature ravines with mesophytic vegetation are found.

The first stage of one of these ravines is merely a shallow groove down the side of the bluff, floored by the bare bedrock and partially choked by rock fragments. The debris accumulates as a cone at the foot. In this stage, a ravine is extremely xerophytic. Few if any plants grow within them, though a few appear upon the talus at the foot. The plants which do appear are the same as the pioneer plants on a cliff face.

The position of such a ravine seems to be determined almost entirely by the surface drainage outside the gorge. Wherever the topography of the surface outside the gorge causes the flood water to be discharged down the bluff, a ravine will be formed. Cleavage planes, which commonly determine the location of ravines in more massive rock, are absent. Seepage lines which often determine ravines in clay bluffs probably have little effect here, for they often occur on cliff faces where no tendency to ravine formation is evident. The rapidity with which a ravine will grow is of course dependent upon the water supply.

Older ravines are generally not regular in gradient, but become very precipitous in some parts. on account of the occurrence of occasional harder layers of limestone. This produces vertical faces from a few inches to six or eight feet in height. and these are usually wet with seepage or run-off from above. These ravines are usually quite deep and well shaded. Vertical faces of the kind described are commonly covered with Cladophora and Vaucheria. Where the water is contaminated by sewage. Oscillatoria replaces these. Mosses grow luxuriantly in these situations, but no liverworts grow anywhere in these ravines. with the single exception of Porella. which is common in mesophytic situations throughout the region. The absence of liverworts is difficult to account for, in view of the hydromesophytic conditions which prevail in such situations. Fimbriaria and Fegatella were found in abundance on damp rock shelves near Thistlethuaite's Falls, north of Richmond. Aneura and Blasia were found on clay in the same region. Marchantia occurs on rocks in similar localities near this point.

Why mosses should be so abundant and liverworts entirely absent in these ravines is difficult to explain. The finding of several genera of liverworts on similar rock shows that their absence is not due to the chemical nature of the rock. The older parts of the Aneura found on clay were stiff

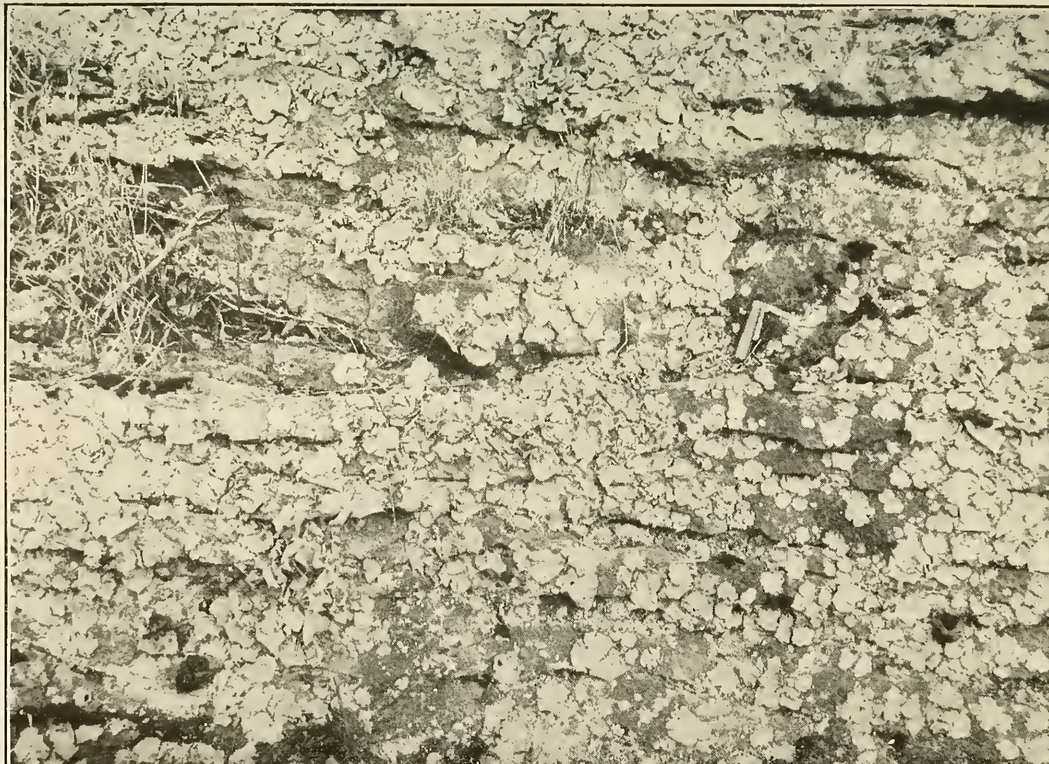


Fig. 9.

Niagara limestone at Elkhorn Falls. Compare character of rock and growth of lichens and mosses with that shown in Fig. 4

with incrustations of calcium carbonate from the seepage water. It is probable that the disintegration of the rock from weathering and stream erosion combined is too rapid to permit the liverworts to maintain a foothold.

The succession from the xerophytic first stage to the ultimate mesophytic stage is very rapid, more so than that of the bluffs. The narrowness of the ravines, the greater amount of shade, and the more constant water supply account for this. The stages passed through are essentially the same as in the case of the bluff.

It is to be noted, however, that until the ultimate mesophytic stage is reached the physiographic factors affect the succession, and that a purely biogenic succession never occurs. In this point the ravine succession differs from that of the bluffs, as already discussed.

That the ultimate stage of the ravine is mesophytic is indicated by the following list of species found in a typical ravine of the region.

Acer saccharum	Vitis vulpina
Quercus prinus	Rhus Toxicodendron
Ostrya virginica	Rubus sp.
Acer negundo	Impatiens biflora
Fagus grandifolia	Impatiens pallida
Fraxinus americana	Ipomœa pandorata
Cercis canadensis	Lobelia syphilitica
Ulmus fulva	Sedum ternatum
Fraxinus quadrangulata	Ambrosia trifida
Gleditsia triacanthos	Viola cucullata
Celtis occidentalis	Eupatorium urticæfolium
Ulmus americana	Sambucus canadensis
Menispermum canadense	Hyrangea arborescens

The successions of the gorge floor are quite as interesting as those of the bluffs and ravines. As already mentioned, the stream is ponded through a large part of the region studied. The conditions which have produced this result have been discussed. In the ponded portions, the water varies in depth from two to five feet, and consequently the current is very slow. As a result of this condition, a typical pond vegetation is found in a number of points within the area. Sagittaria and Typha are characteristic of this condition. Scirpus americanus occurs at a few points. Submerged and floating plants are absent or unimportant. Below the sewers, Oscillatoria is the only form found. Above them, Cladophora, Hydrodictyon and Potamogeton pectinatus occur. Neither Nymphæa nor Castalia is found, probably because of sewer contamination, together with the rocky character of the bottom.

At a number of points, distinct zonation occurs. The succession may be described as composed of five stages, the first of which is always dominated by Sagittaria. Typha makes up the second stage, and is followed by Bidens lævis, which forms the third stage. Where zonation occurs this Bidens zone is always very definite, and usually extends from the edge of the water back two to ten feet. The fourth stage is represented by a zone dominated by Ambrosia trifida and Eupatorium perfoliatum. Other species are Apocynum cannabinum, Bidens frondosa, Xanthium canadense and Verbena urticæfolia. The final stage is represented by Salix nigra, Platanus occidentalis, Vernonia noveboracensis and Aster novæ-angliæ.

Where all five zones occur, they are very closely crowded together. In one instance all were clearly defined in a space of about fifteen feet. Telescoping of stages is common. In two instances, young willows were found in the midst of the zone of Bidens lævis.

The black willows form a very conspicuous feature of the floor of the gorge. They occur commonly in definite lines which parallel the stream at a distance of ten to fifty feet. A very striking example of this occurs just below the Starr piano factory, on the east side of the river. Other lines of trees of this species occur in similar locations farther down the river.

Hydrophytic flood-plains of the usual kind occur commonly in the floor of the gorge. These may be so low as to be covered by the river at every slight rise, or they may be above the level of the highest flood stage. At the main bend of the river lies a high flood-plain of very considerable size. Low hydrophytic flood-plains lie on both sides of the stream immediately at the Starr piano factory. These are narrow, being only a few feet in width at some places. These show a very characteristic vegetation, as shown by the following typical list of species:

Salix nigra	Xanthium canadense
salix longifolia	Rudbeckia hirta
Populus deltoides	Bidens frondosa
Salix cordata	Polygonum virginianum
Ambrosia trifida	Helianthus strumosus
Impatiens biflora	Apocynum cannibinum
Impatiens pallida	Lobelia syphilitica
Rumex crispus	Cicuta maculata

Later stages of the succession occur at other points. The succession is rapid, the flood-plains of this kind quickly become mesophytic. The large flood-plain at the bend of the river is thoroughly mesophytic, as shown by the vegetation of the undisturbed portions of it. It is to be noted, however, that the very narrow flood-plains of this type do not become mesophytic quickly, because of their submergence at every flood. By reason of the high gradient of the stream, the current is swift at flood time, and very little material is deposited. In this respect, these areas differ from the usual hydrophytic flood-plains.

A third feature of the gorge floor is the presence of numerous and well-defined flood-plains of a distinctly xerophytic nature. These occur commonly just below the fall lines, in distinction from those of the sides of the ponded stretches. The manner of their formation is easily seen. As already mentioned, the gradient of the stream is high, and at flood times the swift current carries considerable masses of rock and coarse gravel over the lower land immediately below the various fall lines. As a result, these flood-plains below the fall lines and at the curves of the stream are composed of gravel and rock fragments. The islands at the fall line near the lower end of the gorge are subject to the same conditions.

The vegetation of these areas is quite distinctive. On the upstream side, no plants occur for a considerable distance from the water's edge. This corresponds roughly to the bare lower beach of a lake or the ocean, and is the region that is covered by the slight rises of the river during the summer. The pioneer plants are usually Xanthium canadense and Bidens connata. Back of these occur Salix longifolia, Platanus occidentalis and Populus deltoides. Of these, Platanus is the typical species, and from the bluffs the xerophytic flood-plains may be picked out by the occurrence of this tree, just as the mature hydrophytic flood-plains are indicated by Salix nigra.

Toward the downstream side of these areas, the horizontal succession proceeds rapidly toward mesophytic conditions. Soil accumulates around the trees and the bare rocks and gravel are soon covered. In these locations a rich mesophytic vegetation is found. The following species were noted in such a location:

Salix nigra	Ambrosia artemisiæfolia
Ambrosia trifida	Helianthus strumosus
Bidens frondosa	Eupatorium perfoliatum

It is to be understood that the term "xerophytic" is here used in its broad sense, to indicate that the conditions of plant life are unfavorable in these areas. The extreme thinness of the soil will render water absorption difficult, however plentiful it may be. The range of temperature changes is larger than elsewhere. The trees and other plants are subject to partial submergence at every rise of the river. Perhaps the greatest actual injury comes from floating ice in the winter floods. Sycamores on a xerophytic flood-plain near the bend of the river were more than half cut in two by floating ice, and the upstream side of almost every trunk was dead. The willows commonly show a distinct leaning in the direction of the flow of the river.

We may summarize the results of the investigation as follows: Five distinct plant formations are recognized in the region studied, and each plant association may be referred to one of these five formations: (1) In the rock bluff formation, all stages of the succession from the bare, plantless cliff to a bluff covered by a mesophytic forest, are found within the area under consideration. (2) The same stages of the succession occur in the rock ravine formation. (3) A pond formation occurs at various points of the stream, and the stages of the succession from this condition towards mesophytism may be traced. (4) Definite hydrophytic flood-plains show the usual succession towards mesophytism. (5) Flood-plains of a xerophytic nature occur commonly. The succession to mesophytism in this formation is very rapid. In all of the formations, the trend of the succession is toward a mesophytic forest of the beech-maple type.

Report of Corn Pollination. II.

By M. L. Fisher.

The work reported in 1908 was continued in 1909. The seed from the different crosses reported in the Proceedings for 1908 was planted in 1909. In each lot a number of ears were self-fertilized by hand pollination.

d^1. Boone County White, male; Reid's Yellow Dent, female.

Forty ears were pollinated. Four were pure yellow and thirty-six were mixed. In a count of 2,000 kernels from mixed ears, 204 showed pure yellow, 276 pure white, and 1,520 mixed white and yellow, often cream color. In this connection it is to be noted that it is difficult to tell when a kernel is pure white. The yellow tinge may be so faint that the most careful examination in a good light may not detect it.

d^2. Stowell's Evergreen (Sweet), male; Reid's Yellow Dent, female.

Forty-seven ears were hand pollinated. None was pure sweet or pure dent. Thirteen showed earlier ripening than the others and were smaller in size. There seemed to be a larger proportion of sweet kernels on these ears. The stalks on which they grew were also earlier maturing and smaller in stature. A count of 2,000 kernels showed 322 white, 1,165 yellow, and 513 sweet. The sweet being recessive, the proportion agrees fairly well with Mendel's Law.

d^3. Speckled, male; Reid's Yellow Dent, female.

Sixteen ears were pollinated. Four were pure speckled, twelve were not speckled. Most of those not speckled were pure red, and a few (3) were pure yellow. This also seems to be Mendelian.

d^4. Reid's Yellow Dent, male; Boone County White, female.

The record of the number of ears pollenized has been lost or mislaid, but ears showed the same mixture of kernels as the reciprocal cross, d^1. There were no pure ears. In 2,000 kernels there were 486 pure white, 1,306 mixed, and 208 pure yellow—a close resemblance to the results in d^1.

Various selections were made from the above crosses for 1910 planting, but the data are not in readiness to report at this time.

An Investigation of a Point Discharge in Magnetic and Electrostatic Fields.

By Oscar William Silvey.

A year ago the writer[1] presented at the meeting of the Indiana Academy of Science a report of an investigation of the electric point discharge in a magnetic field of 1,500 gausses. In this work it was found that the stream of air from the negative electrode was in no case deflected, and if the glow discharge existed between the points neither positive nor negative stream was deflected by a field of this strength.

The purpose of the present investigation was to repeat with a stronger magnetic field the work described in the previous report, to study the effect of an electrostatic field upon the path of the spark, and to determine if possible the nature and velocity of the particles composing the stream emitted from the points.

The apparatus used in this and the previous work was that constructed by Professor Foley and Mr. Haseman[2] for the investigation of interference fringes about a point discharge, air streams, and vapor streams. It consisted of a long wooden tube (Fig. 1), one part of which was made to telescope over the other part. This provided a means of separating the two parts for adjusting the points and magnet. Another portion (E, Figs. 1 and 3) containing a plate holder F was made to fit over the end. Black screens (Fig. 4) were placed at intervals throughout the tube so that no light would be reflected from the sides. The end of the tube was closed by a cap (C), which shut out all light except from a pinhole, as shown by Fig. 2. A circular disc with holes of various sizes provided a means of regulating the amount of light. A is a 90° arc light, the center of which is focused on the pinhole by means of the lens B.

Light was shut out of the tube by placing a piece of plack cardboard in front of the pinhole. When a photograph was to be taken, if the discharge was a glow or a brush, the slide S was drawn from over the plate, and after the tube had come to rest, the cardboard was removed until the

[1] Proceedings of the Indiana Academy of Science, 1909.
[2] Not yet published.

plate was sufficiently exposed. In case of the spark discharge which fogged the plate if exposed too long, the cardboard was first removed and the exposure made by withdrawing the slide.

The magnet used was of the Faraday type (photographs, Figs. 7 and 8), with pole pieces 3½ inches in diameter, and with a current of 22 amperes gave, midway between the pole pieces, when 49 mm. apart, a field strength of 6,400 gausses. Longitudinally through the cores and the pole pieces was a hole 2.54 cm. in diameter. If the holes were filled by placing in them an iron cylinder of the same material as the cores, and the air gap reduced to 1 mm., a field strength of 40,000 gausses for a current of 44 amperes could be produced. In most of the

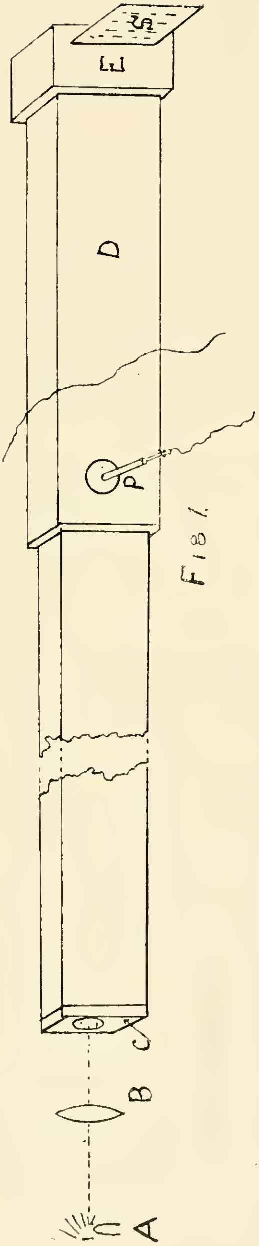


Fig 1.

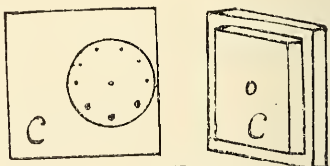


Fig. 2

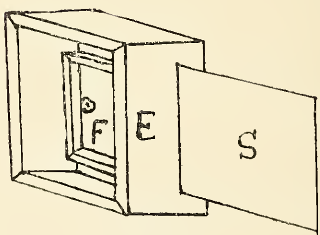


Fig. 3

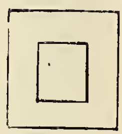


Fig. 4


Fig 6


Fig. 5

following work the air gap was 49 mm. and the current 22 amperes. In order to obtain a photograph of the current which passed between the points transverse to the magnetic lines of force it was necessary for the

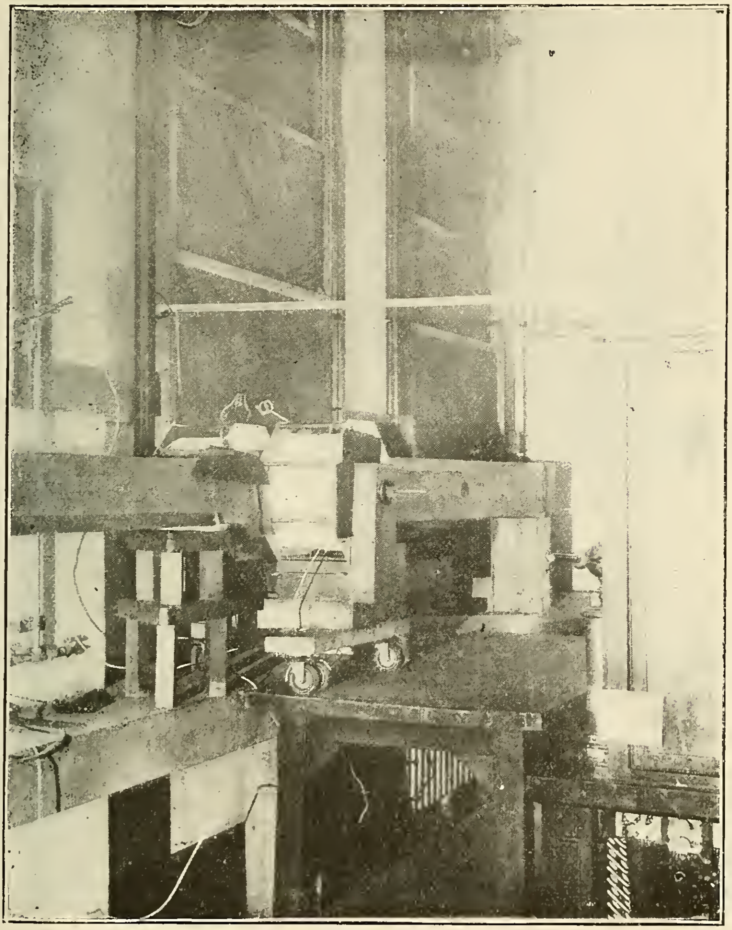


Fig. 7.

light from the pinhole to pass through the hollow cores of the magnet. This was accomplished by fitting the two portions of the tube against the magnet, as shown in photograph, Fig. 8. An auxiliary wooden tube 25 cm. square and 12.5 cm. long was placed between the coils of the magnet to shut out all light except from the pinhole, and to hold rigidly the insulating glass tubes, which firmly held the rods containing the points. An opening was cut in the upper side of this auxiliary tube and a suitable

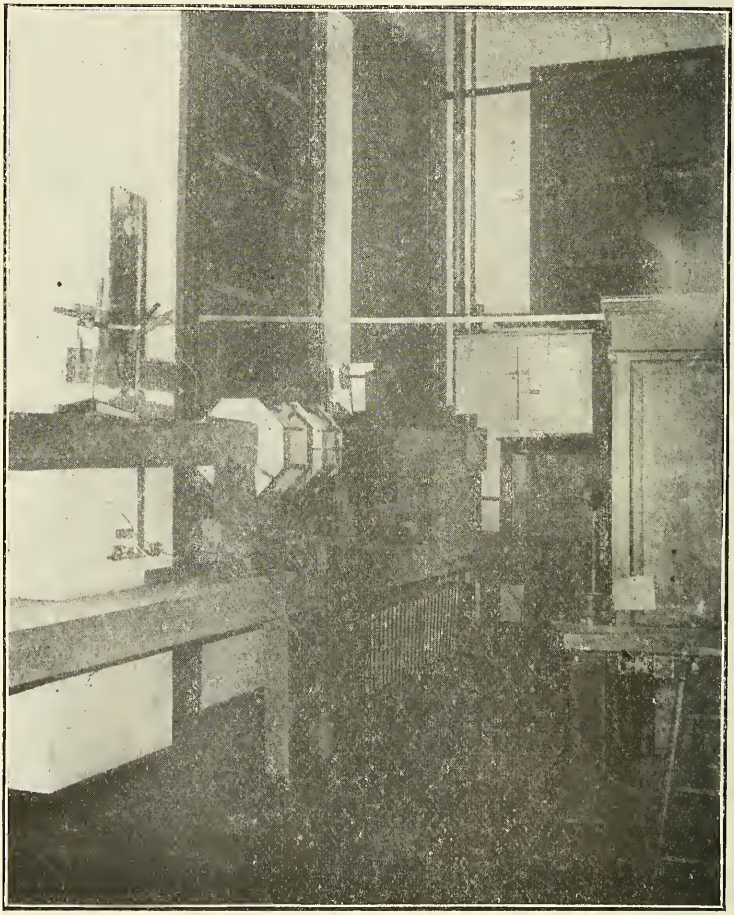


Fig. 8.

cap provided, so that one could easily open it to adjust the points, or to observe the nature of the discharge. The inside of all portions of the tube and the inside of the hollow cores were painted a dead black.

When a photograph of the discharge parallel with the lines of force was desired, the magnet was turned with its axis perpendicular to the axis of the tube, and the glass tubes, held in position by corks in the hollow cores, provided insulation for the rods holding the points. In this case also an auxiliary tube 12.5 cm. square and 1 meter long was placed between the coils and telescoped into the two portions of the longer tube which were too large to fit between the coils. This small tube had a circular hole in each of two sides to receive the pole pieces of the magnet, and another in the upper side similar to the one in the first auxiliary tube described.

In all cases the magnet was electrically connected to earth and the wires bearing the current were separated from the walls of the room and from the camera by means of glass tubing, when they were too near for the air to insulate them. All metal parts used in the magnetic field, such as screws in the auxiliary tubes, were of brass.

When studying the deflection of the discharge due to electrostatic deflection, the tube was used as shown in Fig. 1. Two brass plates 8 by 5 cm. were placed one above the other below the points. They were held in position by brass rods soldered perpendicularly to them at the center. The rods were firmly fitted into glass tubes which passed through the upper and lower sides of the tube. For part of the work the plates were connected electrically in multiple circuit with the points, while for the other part they were charged by means of a small Holtz machine. The points were charged by a four-mica plate Wagner electrostatic machine, from which the Leyden jars had been removed. Both the Wagner and the Holtz machines were run by electric motors with rheostats in circuit for varying the speed. Sixteen different speeds were possible with the Wagner, and eight with the Holtz machine.

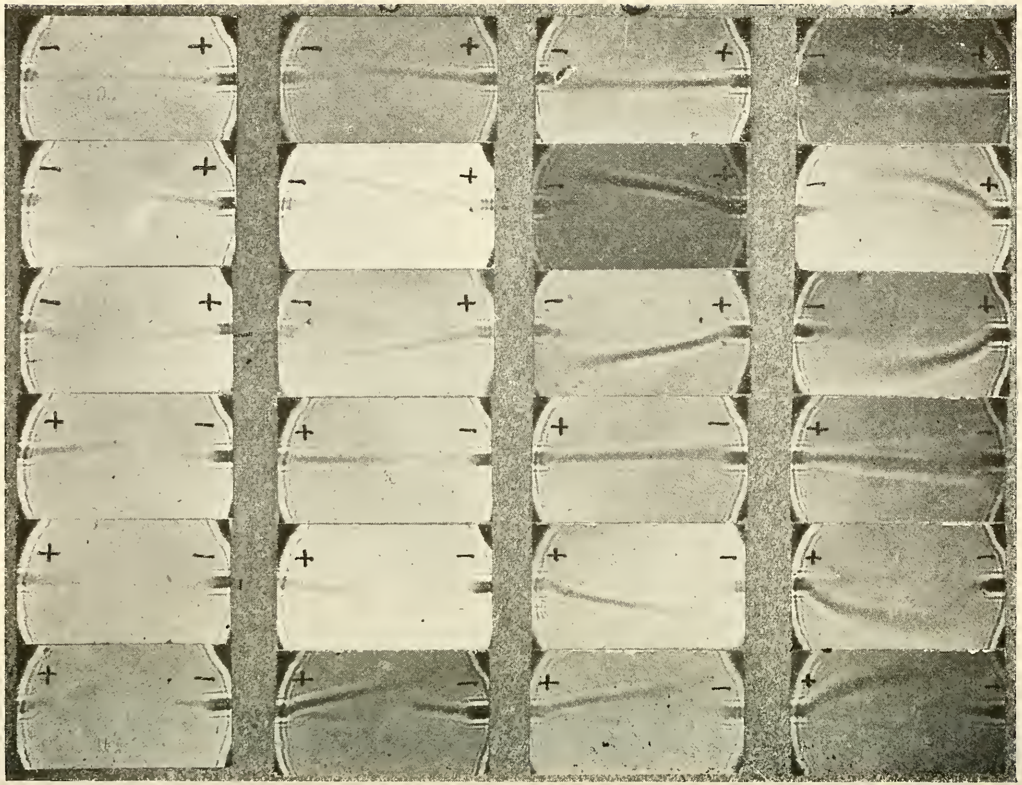
The points were made of brass pins 1.15 mm. in diameter and 4 cm. long. They were put in a lathe, sharply pointed by means of a carborundum stone, and made to slope 2.5 cm. from the end. They were soldered into the ends of brass rods 5.57 mm. in diameter.

TRANSVERSE MAGNETIC FIELD.

The apparatus was first adjusted with the points at right angles to the direction of the magnetic lines of force and the photographs of series A, B, C and D were taken.

Plate I. Transverse Magnetic Field.

No. 1.
No. 2.
No. 3.
No. 4.
No. 5.
No. 6.



A B. C. D

No. 1. Current 1st, No. 4. Current 2nd direction, magnetism (none).
No. 2. " " No. 5. " " " " 1st direction.
No. 3. " " No. 6. " " " " 2nd "

Series A is a glow discharge representing the lowest speed of the machine. (Nothing was visible between the points in the darkened tube. Each point showed a tiny bright speck.)

Series B is a brush discharge representing a higher speed. (A violet stream extended about 0.8 cm. from the positive point. The negative point showed only a bright speck.)

Series C is a visible spark discharge representing the lowest speed at which a visible spark is maintained. The spark was changed to brush when the magnet was excited.

Series D is a visible spark discharge representing the highest speed of the machine.

The six numbers of each series were taken in succession as rapidly as possible, it requiring 20 to 30 minutes to complete the series. In the photographs, the longer stream is the one from the positive terminal and the shorter one the stream from the negative electrode. If the positive stream is from right to left it is designated as the first direction; if from left to right as second direction. Nos. 1, 2, 3 then show current in the first direction, while Nos. 4, 5 and 6 show current in the second direction. If the magnet was excited so that the sense of the lines of force was from back to the front of the photograph (i. e., after correcting for the reversal in direction caused by printing from the plates), the magnetization is designated as first direction and those with the lines of force from front to back of the page are designated as magnetized in the second direction. Following then this plan, Nos. 2 and 5 show the current in a field of the first direction, while Nos. 3 and 6 show the current in a field of the second direction, and Nos. 1 and 4 show it when the magnet was not excited. It may be observed from the photographs that the streams in series A, B, C and D are deflected as if they were flexible conductors bearing a current in so far as direction of deflection is concerned, thus indicating that the stream is one of charged particles.

The magnetic field strength, measured by a bismuth spiral, was about 6,400 lines per sq. cm. in the region of the points. The points were 18.05 mm. apart. The potential of the points was the highest for series B and did not increase as the speed increased, as was suggested in the earlier work. The potential increased with the speed only until the sparks began passing, when it fell sometimes as much as 4,000 volts. When the speed was further increased, the current increased but the potential remained practically constant. The following table shows the changes which occurred as the speed of the machine was increased:

Potential expressed in volts, current expressed in amperes. Distance between points, 18.05 cm.

TABLE 1.

Speed	Voltage before magnet was excited	Voltage with Magnetism	Current no Magnetism	Current with Magnetism	Type of discharge. Effect of magnetism on form of discharge
1	23000	24000	.00014	.00014	Glow discharge.
2	24500	24500	.00017	.00017	" "
3	25300	25300	.00021	.00021	Small brush at anode.
4	26200	26200	.00025	.00025	Increased brush at anode.
5	26500	26500	.00029	.00029	Occasional spark.
6	27000	28300	.00035	.00035	Spark changed to brush by magnetism.
7	25300	28300	.00037	.00037	" " " " " "
8	24000	28300	.00044	.00044	" " " " " "
9	23000	28300	.00052	.00049	" " " " " "
10	22800	28300	.00059	.00054	" " " " " "
11	22800	28300	.00058	.00056	" " " " " "
12	23000	28300	.00065	.00059	" " " " " "
13	22800	28300	.00072	.00069	" partially changed to brush by magnetism.
14	22300	26500	.00078	.00076	" " " " " " "
15	22300	25000	.00083	.00083	Path curved but spark not stopped.
16	22300	25000	.00086	.00084	" " spark scattered.

In the above table, the current was measured by means of a Weston milli-ammeter, and the potential by means of an electroscope. This electroscope was made of two brass discs 10 cm. in diameter mounted in vertical planes on ebonite supports which were fitted to a common base. The distance between the plates could be varied by moving the supports. At the top of one of the discs was soldered a support holding a small needle upon which was suspended a brass vane which carried a pointer at the lower end. The pointer moved in front of a scale which was calibrated by connecting in multiple with the discs two No. 12 Thomas Harper needles (sharps), measuring the critical spark length between them and comparing with the table prepared by H. W. Fisher.[3] The position of the pointer was read through a telescope placed two meters in front of the scale. The potential read by this apparatus amounted to only a rough estimate, since it could not safely be trusted nearer than 150 volts. This was especially true when the sparks did not pass rapidly in succession because the vane

[3] H. W. Fisher, Transactions of International Electrical Congress, Vol. 2, pp. 294-312, St. Louis, 1904.

vibrated, rising almost to the critical spark potential, and falling almost to zero. In this case the mean position was recorded.

It may be observed from the above data that when the form of discharge was not changed by the magnetic field, there was no change in the current or the potential, and that when the form of discharge was changed there was an increase in the potential, and often a decrease in the current. The photographs of series A correspond to speed 1, B to speed 4, C to speed 6, and D to speed 16.

LONGITUDINAL MAGNETIC FIELD.

After taking the above data the magnet was turned through an angle of 90°, and four series of photographs taken of the discharge parallel with the lines of force. These are as follows:

E—silent glow discharge same as A.

F—brush discharge same as B.

G—spark discharge same as C.

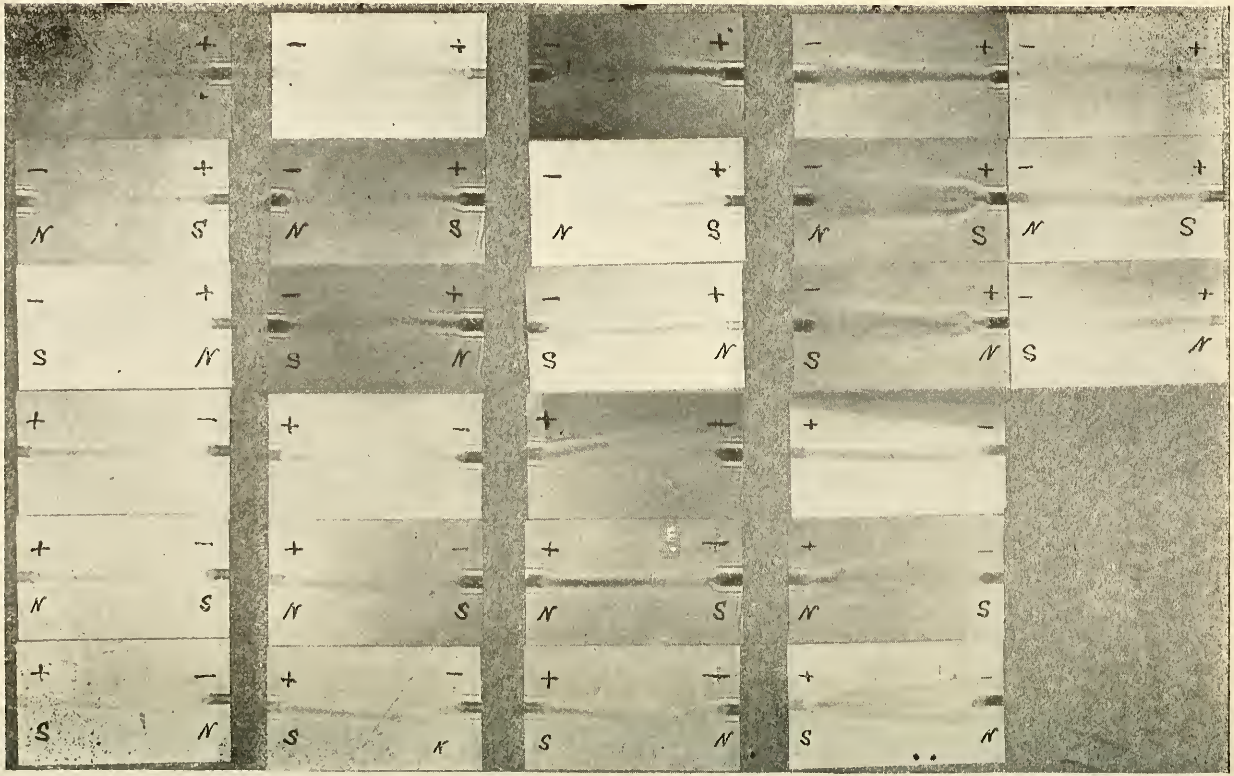
H—spark discharge same as D.

Distance between points, 17.88 mm.

Of these photographs, none show a change of form except those of series H. In this case the rich spark was sometimes scattered, and sometimes transformed to a wide violet brush at the positive point when the magnet was excited. In the first case it generally consisted of a visible undeflected central thread, with spiral thread encircling it like the threads of a tapering screw, the larger diameter of the spiral being at the positive point, and all merging together at the negative terminal. Sometimes, however, the central thread was absent and only the spiral showed. The sense of the rotation of the spiral was the same as that of the halo of luminous gases about the spark of an induction coil in a longitudinal magnetic field. In degree of deflection it was much less. In the case of the discharge studied here, the spiral was only a few millimeters in diameter in a magnetic field of 6,400 gausses, while the halo about the spark of an induction coil showed a spiral of four or five centimeters in diameter in a field of about 1,000 lines per square centimeter. Photographs 3 and 5 show the point discharge when the positive ions move in the same direction as the lines of force, while in Nos. 2 and 6 the magnetic field is in the opposite direction to that of the discharge. Unless there was a change of form of discharge, no change of potential nor of current occurred when the magnets were excited. Some changes of potential with transformation of form of discharge are as follows:

PLATE II. LONGITUDINAL MAGNETIC FIELD.

No. 1.
No. 2.
No. 3.
No. 4.
No. 5.
No. 6.



E. F. G. H¹. H².

No. 1. Current 1st, No. 4. Current 2nd direction, magnetism (none).
No. 2. " " No. 5. " " " " 1st direction.
No. 3. " " No. 6. " " " " 2nd "

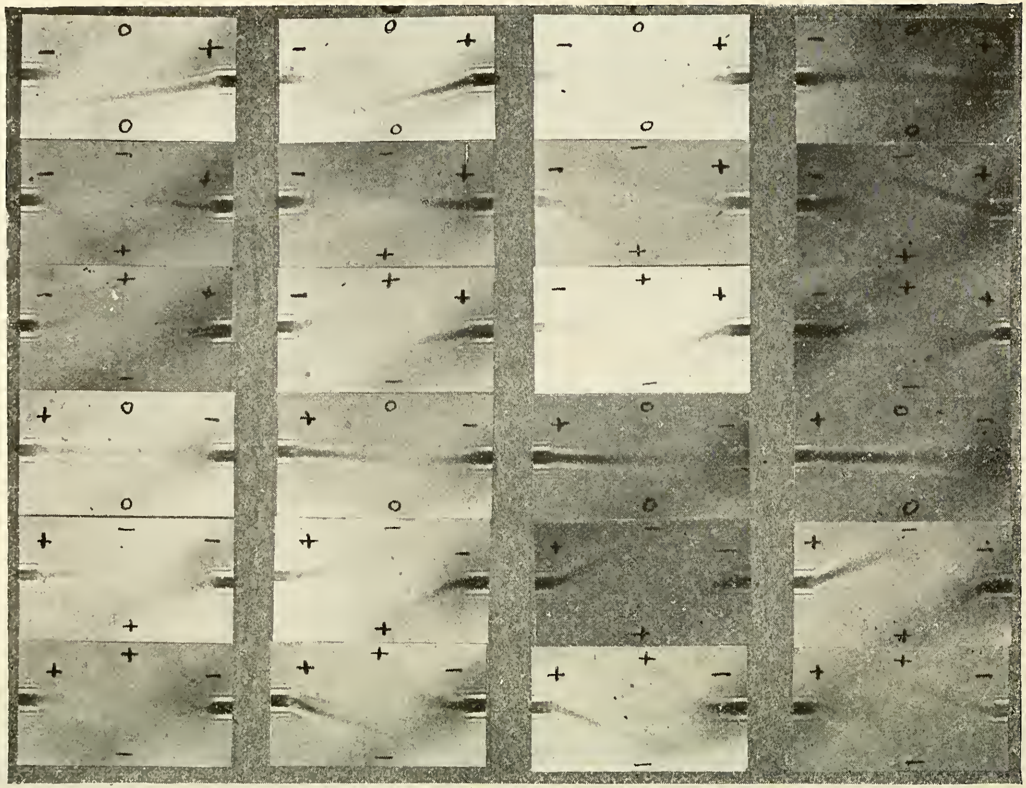
TABLE 2.

Speed	Voltage before Magnet was excited	Voltage with Magnetism	Type of discharge Effect of Magnetism on form of discharge
1	21500	21500	Glow.
2	22000	21850	Small brush.
3	22500	22000	Occasional spark.
4	20000	22500	Changed to brush by magnetism.
5	22500	22500	No change.
6	20000	22500	Changed to brush.
7	18800	26500	" " "
8	18800	24000	" " "
9	18800	23500	" " "
10	18800	18800	No change.
11	18150	25000	Changed to brush.
11	18150	18150	Not changed to brush.
12	18150	18150	No change.
13	18150	24000	Changed to deflected scattered sparks.
14	18800	25000	Changed to brush.
15	18800	24000	Scattered deflected sparks.
16	18500	25000	Changed to brush.

The above table shows that there is no regularity in the changes in the discharge due to the influence of the magnetism. In No. 11 the spark discharge was entirely changed to brush for a while, then broke into a spark again, changing sometimes two or three times per minute. When the exciting current was stopped the sparking was again resumed. In the many complete sets of readings similar to the above it was found that this change appearing in No. 11 occurred for any of the spark discharges, but the actual condition that caused it was not discovered. One could not foretell when the discharge would be altered by the influence of the magnetism. Series H_2 shows photographs of the same sort of discharge as H_1, in which there was no change due to magnetism. These were taken twenty-four hours later than those of H_1, and on this particular day no change occurred in the discharge, when the current was in the direction shown in H_2, while on the previous day, with the same conditions in so far as apparatus was concerned, the spark was changed to brush every time the exciting current was closed, regardless of the direction of the magnetism. In series H_2 the spark was changed to brush by the magnetism when the other point was made positive, the photographs being like the corresponding ones of series H_1.

Plate III. Transverse Electrostatic Field.

No. 1.
No. 2.
No. 3.
No. 4.
No 5.
No. 6.



I. J. K. L.

No. 1. Current first direction, No. 4. Current second direction; no charge on plates.
No. 2. " " " No. 5. " " " upper plate negative.
No. 3. " " " No. 6. " " " " " positive.

TRANSVERSE ELECTROSTATIC FIELD.

The magnet was then removed and the deflection of the discharge studied in an electrostatic field. With the apparatus as previously described and with the electrostatic plates, the points and the electroscope shunted in parallel circuit, the four series of photographs I, J, K and L were taken. The following is a record of the potential and the current in each case, the forms of discharge for series I, J, K and L corresponding to those of A, B, C and D respectively:

Distance between points, 18.05 mm.

Table 3.

No. in Series		Charge on bottom Plate	Sign of Right hand point	Potential in Volts	Current in Amperes	
I	1	none	+	17850	.00019	
	2	+	+	17700	.00019	
	3	—	+	17600	.00016	
	4	none	—	16270	.00016	
	5	+	—	15150	.00015	
	6	—	—	16270	.00015	
J	1	none	+	18900	.00027	
	2	+	+	19425	.00036	
	3	—	+	19500	.00036	
	4	none	—	14700	.00026	
	5	+	—	17400	.00026	
	6	—	—	17250	.00026	
K	1	none	+	16800	.00039	
	2	+	+	17700	.00051	
	3	—	+	19200	.00052	Changed to brush.
	4	none	—	15600	.00052	
	5	+	—	17900	.00052	
	6	—	—	18370	.00051	Partially changed to brush.
L	1	none	+	16725	.00092	
	2	+	+	18000	.00089	
	3	—	+	17700	.00091	
	4	none	—	13950	.00088	
	5	+	—	16875	.00094	
	6	—	—	16800	.00090	

The variation of the potential and current in any series in the above table except for (3 and 6) K, was due to a decrease of speed of the motor. This was caused by a drop in potential when a large current was used in some other part of the building. It required at least two hours to complete the four series. The current and potential were read just before the photographic plate was exposed.

ELECTROSTATIC AND MAGNETIC FIELDS.

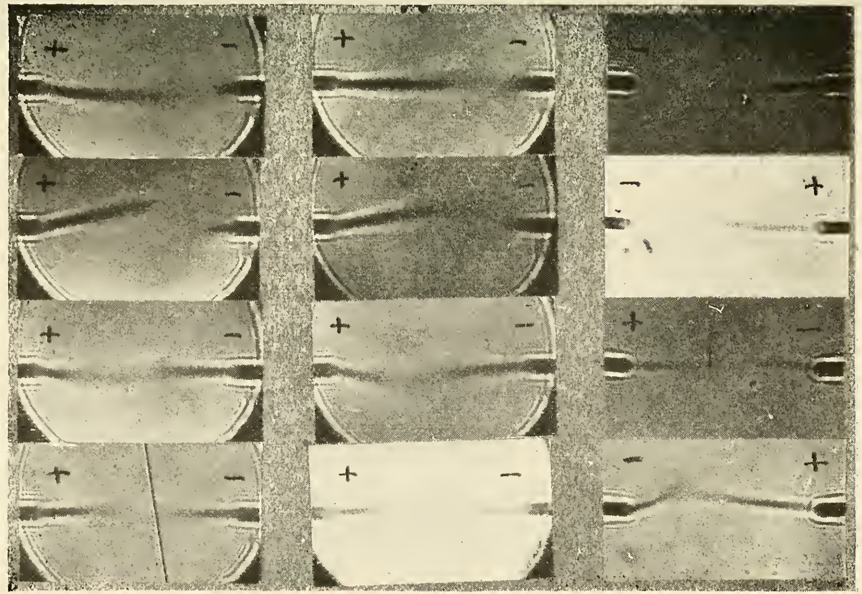
The magnet was again placed in the position so that the line of discharge between the points was transverse to the magnetic lines of force, and with the electrostatic plates above and below the points, an attempt was made to balance the effect of the electrostatic field against that of the magnetic field. In this work the plates were charged by a Holtz machine with plates 43 cm. in diameter. A ground glass placed in the end of the camera opposite the pinhole showed clearly the path of discharge. The speed of the Holtz machine and the strength of the exciting current of the magnet were then regulated until the stream under the action of both fields was the same as when no field influenced it; then, the ground glass was removed and was replaced by a photographic plate. Two series of these photographs are shown here, M, for the spark discharge which, under the influence of magnetism alone was changed to brush, and N for the rich spark. It was not difficult to balance the two fields in the case of the rich spark, but with the unstable spark they were not successfully balanced. Sometimes with this type a very low magnetic field seemed to predominate over the electric field. This, if true, conforms with the statement made in the previous report that the magnetic effect is greatest when the discharge is on the verge of changing from one form to the other. Data as follows:

Distance between points, 18.05 cm. H is the magnetic field strength in gausses.

TABLE 4.

	Distance between Plates in cm.	Potential Difference in Volts	Potential Gradient = X	H	Velocity of Ion	Form of Discharge	Values for $\frac{e}{m}$	
1	5.4	14600	2710	4300	6.3×10^7	small brush	7.8×10^2	
2	5.4	14600	2710	4300	6.3×10^7	occasional spark	7.5×10^2	
3	5.4	15000	2780	2550	1.9×10^8	" "	7.1×10^3	
4	5.4	15000	2780	3800	7.4×10^7	rich spark	1.2×10^3	
5	6.1	26800	4360	1600	2.7×10^8	spark	1.36×10^3	Series M
6	6.1	26800	4360	1600	2.7×10^8	rich spark	1.36×10^3	Series N

PLATE IV. ELECTROSTATIC AND MAGNETIC FIELDS.



No. 1. (M and N) magnetic and electrostatic fields opposed.
No. 2. (" " ") deflected by electrostatic field.
No, 3. (" " ") " " magnetic "
No. 4. (" " ") neither magnetic, nor electrostatic field.
Nos. (1 and 3) O discharge undisturbed.
Nos. (2 and 4) O " deflected by air stream.

It seems probable that the speed of the ion might be calculated from the relative deflection of a similar form of discharge under influence of the magnetic and electrostatic fields separately. The distance between the points was the same in both cases and therefore the potential at the points would, no doubt, remain of the same order, even though there was some change. On the photographs a line may be drawn directly between the points, and a second line drawn through the extremity of the negative electrode perpendicular to the first line. If then a third line is drawn from the positive point in the direction of the deflected stream and extended to meet the second line, the distance to the intercept of the second and third lines from the extremity of the negative electrode should be proportional to the deflection. Taking the distance to this intersection for the upward deflection, we have:

$Hev = K \tan \theta_1$, in case of the magnetic effect where H is the magnetic field strength in gausses, e the charge on the ion, v the speed of the ion, θ_1 the angle of deflection, and K is a constant which depends on the potential drop along the path of discharge.

In case of the electrostatic deflection, $X e = K \tan \theta_2$ where X is the potential gradient between the electrostatic plates and θ_2 the angle of deflection.

Solving each equation for K we have

$$K = \frac{Hev}{\tan\theta_1}, = \frac{Xe}{\tan\theta_2}$$

If the h_1 and h_2 are the distances from the negative point to the intercept in the two cases, and l the distance between the points, we have

$$(Hv \tan \theta_2 = X \tan \theta_1), \quad \frac{Hvh_2}{l} = \frac{Xh_1}{l}, \text{ and } v = \frac{h_2 X}{h_2 H}$$

Since the discharge does not always pass directly between the points when no transverse field exists, it would probably be more accurate to take the average value of h for the upward and downward deflection. Making the suggested measurement in case of photographs 2 and 3 of series A and 2 and 3 of series I, we have

$$V = \frac{2.8 \times 17600 \times 10^8}{3.2 \times 5.1 \times 6400} = 4.7 \times 10^7 \text{ cm. per. sec.}$$

Values for other photographs calculated by the same method appear in Table 5.

The above values for the speed of the positive ions approximate those given for positive ions in rarefied gases. The highest value obtained by other investigators for the gaseous ion at atmospheric pressure, found recorded by the author, is by Helen E. Schaefer of 5×10^4 cm. per second. Her value, obtained by use of a rotating mirror, is given as the average speed along the spark path, and not the initial speed obtained by the method used in this investigation.

The curved path of the stream in series D can not be considered in connection with the ordinary formula for centripetal force in solving for a value for the ratio of the charge to the mass, because here the ion is under the influence of the charge on the opposite point. If, however, the value obtained by the above method can be regarded as the initial speed of the positive ion the equation $\frac{1}{2}mv^2 = Ve$ can be used to calculate the value for $\frac{e}{m}$. In the above equation m is the mass of the ion, v its speed, V the potential between the points and e the charge on the ion. Since v is the initial speed the two expressions for the energy are independent of the course taken by the ion between the points, and also independent of any subsequent speed. Some values of $\frac{e}{m}$ calculated by means of this expression are as follows:

$$\text{Series A Nos. 2 and 3) } \frac{e}{m} = \frac{1}{2}\frac{v^2}{V} = \frac{1}{2}\frac{(4.7 \times 10^7)^2}{23000 \times 10^8} = 4.6 \times 10^2 \text{ cm. per. sec.}$$

TABLE 5.

Series.	Nos. in Series.	Speed v in cm. per. sec.	$\frac{e}{m}$
A and I	2 and 3	4.7×10^7	4.6×10^2
A " I	5 " 6	1×10^8	2.17×10^3
B " J	2 " 3	2.6×10^7	1.3×10^2
C " K	2 " 3	6×10^7	6.7×10^2
C " K	5 " 6	2.7×10^7	1.3×10^2
D		1.6×10^8	5.12×10^3

The average speed of all results is used in determining the value of $\frac{e}{m}$ given for series D. The values for $\frac{e}{m}$ column 4 are calculated for series A, B, C and D only. The values for $\frac{e}{m}$ given in table 4 are determined in the same manner as shown above.

A great variation exists in the calculated values of the speed, and consequently in the determination of $\frac{e}{m}$. One cause for this is, no doubt, the error introduced in measuring the potential. Also since the measurement of speed is determined by deflection, a large error may be introduced, due to convection currents, due to the heated air along the course of the spark, and to disturbances of the air due to rapid changes of pressure along the spark path.

It may be observed that the path of the stream from the point (except in case of the spark discharge in the magnetic field), is a straight line and not a curved path. There is very little if any bending to meet the opposite point. If we consider the stream as composed entirely of ions we might explain this phenomenon by supposing that the ions either lose their charge immediately after leaving the points, or by assuming that each ion is given a constant acceleration in two directions at right angles to each other. Another view may probably be taken in which the photographed stream is considered to be a mixture of ions and air molecules under different pressure than the surrounding air, hence having a different index of refraction. The ions start at a high speed from the point in a direction which depends on the influencing fields. They soon encounter molecules of air imparting their speed to a great extent to the air molecules. This bombardment on the air molecules tends to ionize them and to raise their temperature and the original ions, with the ionized and un-ionized molecules of air continue a short distance at least, in the original direction. The unionized air particles would continue along this line until scattered by encountering new molecules, while the ions, too much scattered, and with speed too much decreased to produce a well defined air current, travel by some other route to the opposite electrode.

This view explains the apparent contradiction that, although there must be a carrier of electricity between the points, the photographed stream does not terminate on the opposite point. In case of the rich spark, which takes on more and more the form of an arc as the speed of the machine increases, the air insulation is broken down, the air is more highly heated and more highly ionized along the spark path, and a greater number of ions will travel along this narrow path with great speed and due to the outer ones encountering the air molecules, the stream will follow more nearly the curvature of the spark. Farther from the point their speed becomes so small and they become so much scattered, they do not set up a stream so well defined. This same hypothesis applies to the explanation of the scattered stream when it was deflected by an electrostatic field. The stream retains practically its original diameter past the opposite terminal for the magnetic deflection in case of the glow and brush discharge, and although scattered may be traced nearly to the opposite point in the spark discharge. In case of the electrostatic deflection, the discharge without the transverse field is quite as well defined as those of the magnetic deflected series, while with the transverse electrostatic field the stream is short and not so well defined. If the ions moving with great speed start from the point, and soon by their bombardment start a current of air, at the same time lowering their own speed, they will certainly be scattered, part of them going to the oppositely charged plates, and part to the opposite point.

If the majority of the negative ions are considered to be ordinary electrons and those from the positive point equal in mass to the hydrogen atom, the kinetic energy of the positive ions will be far greater than the negative. They will therefore carry with them a greater current of air. Perhaps it may be permissible to assume that the negative ions are not all single electrons, since it has been shown by J. J. Thomson[4] in case of discharge is rarefied gases, that negative ions exist nearly equal in mass to the positive ions, and have the same initial speed. The greater the per cent. of these large ions the greater will be the amount of air set in motion, the greater the velocity of the stream as a whole, and the more defined the stream. If, then, the assumption is made that the stream is produced by the larger ions, it explains the equal deflection of the positive and negative streams in case of the magnetic deflection.

A few of the photographs show peculiar characteristics. In some there are two streams from the positive point. It was not learned whether

[4] J. J. Thomson (Phil. Mag. Ser. 6, Vol. 16, pp. 657-691), 1908; also (Phil. Mag. Ser. 6, Vol. 18, pp. 821-844), 1909.

this was caused by two branches of the discharge, or by a change of direction of the discharge during the exposure, but the clear interference bands about the stream indicate that the former is correct. Another is the peculiar deflection of the negative stream of No. 6 F. Many photographs were taken and many observations were made with the ground glass in an attempt to secure a duplicate of this, but with no success.

In the previous work the negative stream was not deflected by a magnetic field of 1,500 gausses, but in this the deflection was well shown where the stream is clear enough. The negative stream is in very few cases as long or as well defined as the positive. Also in the previous work, it was found that if the knobs of the electrostatic machine were placed sufficiently close together, a spark passed between them, while between the points there was a violet stream, which was not shown on the plate or perceptibly deflected by the magnetic field. An attempt to deflect this stream with a stronger field was not successful.

In repeating the work of Precht[1], particular attention was given to his observation with the point cathode and the blunt wire anode, that the spark changed to brush and the potential rose when the magnet was excited. The writer found that this change occurred in a great majority of the observations made, but it was found to occur also in as great a per cent. of the observations, whether the discharge passed between the points, point anode and blunt wire cathode, or point cathode and blunt wire anode, whatever the sense of the magnetism with reference to the current. In a few cases a brush would break into a rich spark, but all attempts to determine the conditions which caused the changes were unsuccessful. In the previous report it was suggested that in case of the discharge between two points the change in type of discharge might be explained as a result of a change of the spark length, but after repeating the experiment it was concluded, as was suggested by Precht[5], that although the length of spark path might be partly the cause, it was not the whole cause. No attempt was made to reproduce the exact condition of Precht's experiment either in the form or size of the point, but no doubt if these had been fulfilled the atmospheric and other conditions would have entered which would have made the results variable because with no part of the apparatus altered in any way entirely opposite transformations were found to exist on different days.

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[5] J. Precht, Wied. Annalen (66-4, pp. 676-697), 1898.

As a final study three mg. of radium bromide were placed beneath the points, in an attempt to change the form of discharge, as described by A. E. Garrett[6], for discharges between blunted wires. The radium, which was contained in an unstoppered glass tube, was held by an ebonite rod so that both α and β particles might reach the air in the path of discharge. No effect was observed except that which could be produced by a glass rod in the same position.

SUMMARY OF RESULTS.

A summary of the results, as given in this and the previous report, is:

(1) The positive stream between the points for a spark or brush discharge was deflected by a magnetic field as low as 1,000 gausses, and both positive and negative streams for glow, spark and brush discharge were deflected by a magnetic field of 6,400 gausses. In all cases the direction of deflection was in accordance with electro-dynamical laws.

(2) In most cases a change of type of discharge, and an increase of potential between the points was caused by excitation of the magnet.

(3) The direction of the photographed stream for a spark discharge as it leaves the point is the same as the visible direction of the spark.

(4) The size of the stream at the points (measured with a micrometer microscope between the outer edges of the central dark band) is independent of the potential between the points.

(5) The stream was deflected by an air current, the negative being deflected more than the positive.

(6) The stream for the richer spark (i. e., for the higher speeds of the machine) increased in width as the distance from the point increased, while the stream for the glow discharge retained its original size as far as it could be traced.

(7) The stream was deflected by an electrostatic field, in which case it was shorter and more scattered than in case of the magnetic deflection.

(8) Values for the speed of the ion were calculated from the angle of deflection, in magnetic and electrostatic fields, and by placing the two fields in opposition. The average of these was 1.6×10^{8} cm. per second.

(9) From the kinetic energy of the moving ion and the product of the potential between the points and the charge on the ion values for $\frac{e}{m}$ are calculated, the average value found being 1.8×10^{3}.

[6]A. E. Garrett, B. Sc.—The Phys. Soc. of London Proceedings, Dec. 1909, page 643.

(10) A suggestion is given that the stream consists of heated air molecules and ions, in which the latter soon lose their velocity, due to encountering air molecules, and travel to the opposite point with a speed too much decreased to set up an air current, along a route determined by the two fields, while the un-ionized air moves in the direction given it by the ions at the point.

The above investigation was suggested by Professor Arthur L. Foley, of Indiana University. I wish to thank him and Professor R. R. Ramsey for their helpful suggestions during the course of the investigation. I wish also to thank Professore A. T. Jones and C. M. Smith, of Purdue University, for their criticism during the preparation of this report.

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The Huron Group in Western Monroe and Eastern Greene Counties, Indiana.

By F. C. Greene.

The opening of the right-of-way of the Indianapolis Southern Railway between Indianapolis, Indiana, and Effingham, Illinois, presented an unusual opportunity for the study of the so-called Huron group, west of Bloomington, Indiana, in western Monroe and eastern Greene counties. The Huron group is the youngest formation of the Mississippian of Indiana. The name Huron was first applied by Dr. Ashley in his paper on the Lower Carboniferous Area of Southern Indiana.[1]

The type locality is at Huron, Lawrence County, a station on the B. & O. S.-W. Railway. According to his definition, the boundaries of the Huron group are fixed at the base of the lowest sandstone in the group and the unconformity at the top which marks the division between the Mississippian and Pennsylvanian. The discussion of his reasons for so drawing the limits at these points may be found in his report and will not be repeated here. However, as the name Huron is preoccupied[2], it must be replaced by another, and it is here proposed to substitute the name Chester, as the group can be correlated with the upper Mississippian of Illinois or Kentucky.

Blatchley gives a concise summary of the formation.[3] He says, "In Orange County, where the Huron group is perhaps the most typically exposed, it is represented by a lower limestone, a lower sandstone, a middle limestone, an upper sandstone and an upper limestone. . . . . .

The lower Huron limestone is a compact, smooth-grained, ash-gray to blue limestone, which varies from five to eight feet in thickness. In structure it is a close-grained, fine-textured, non-crystalline stone, breaking with a sub-conchoidal fracture. . . . . .

[1] Ashley, G. H., Dept. of Geol. and Nat. Res. of Ind., 1902.

[2] In the Rept. of Progress in 1869, Geol. Survey of Ohio, Part I, p. 18, Dr. S. W. Newberry proposed the name Huron for a shale formation of the Devonian of Ohio.

[3] Blatchley, W. S., Thirtieth Ann. Rept. Ind. Dept. Geol. and Nat. Res., pp. 144-145.

The middle Huron limestone is usually a close-textured, semi-crystalline, gray fossiliferous limestone which varies in thickness from 5 to 30 feet, averaging about 16 feet. . . . . .

The upper limestone averages about 15 feet in thickness, is more nearly crystalline in structure, varies from dark to light gray in color, and contains many crinoid stems and bryozoa. It takes a fine polish and resembles marble when so treated, but does not hold its polish when exposed to the atmosphere.

The general section in the area under discussion is:

		Ft.
	10—Shale and sandstone of Pennsylvanian age, which is unconformable on the beds below. Huron (Chester) Group.	
Upper limestone.	9—Limestone and shale, calcareous, grading from brecciated limestone at bottom to shale at top; limestone composed largely of bryozoa with few foraminifera; locally known as marble...........	25
Upper sandstone.	8—Sandstone, a heavy bed of ferruginous, reddish, brown, or white, hard or soft, laminated................	40
Middle limestone.	7—Limestone, crystalline, generally light colored, occasionally oölitic, foraminiferal.................	6–21
Middle sandstone.	6—Shale, argillaceous or arenaceous, weathers red in places	20–25
	5—Sandstone, similar to upper, except much more cross-bedded	25
	4—Shale, dark, bituminous...........................	0–12
Lower limestone.	3—Limestone, thin bedded, oölitic or lithographic.......	2–5
Lower sandstone.	2—Shale, arenaceous or sandstone..................	½–12
	Mitchell limestone.	
	1—Limestone, white, finely oölitic.	

SUMMARY OF PREVIOUS WORK.

Cox, in a report on the geology of Greene County[4], says:

"Sub-Carboniferous Limestone.—At the mouth of Fish Creek, in the northern part of the county, limestone belonging to the Chester group of the sub-carboniferous formation, outcrops in the bluff bank of the creek, and is exposed to the depth of 15 to 20 feet, and is at this place overlaid by drift, but at a short distance to the southwest it is increased by the addi-

[4] 1st Ann. Rept. Geol. Survey Ind., 1869, p. 87.

tion of 2 to 5 feet of shale, with an irregular thin bedded seam of Coal A and the Millstone Grit. Some of the layers contain a few fossils. The following comprise all that could be recognized: Orthis umbraculum, Archimides wortheni, Athyris subtilita, Pentremites obessus, P. pyriformis, Spirifer incrassatus, Productus carbonarius, P. cora, and an abundance of encrinite stems. It belongs to the upper member of the sub-carboniferous limestone, and is designated by Prof. A. H. Worthen in the Geological Report of Illinois as the Chester Group.

"The greatest development of this limestone seen in Greene County, is on Beech Creek, a branch of Richland Creek, on section 12, township 7, range 4, where it forms a great mural precipice, capped with sandstone of the Millstone Grit series. The following section was obtained at this locality:

"Brownish-gray sandstone, in thick beds which has the appearance of being most excellent building stone............	25 feet 0 in.
Shale, which thickens up to many feet and in places contains Coal A	1 in.
Buff colored limestone in which I saw Pentremites obessus, P. pyriformis, and Archimides wortheni..................	20 feet
Gray silicious shale, partly covered........................	25 feet
Bluish limestone (in which I saw no fossils, with intercalations of sandstone, mostly covered by talus................	50 feet
Total	120 feet 1 in.

"At the junction of the sandstone and limestone at this locality, there gushes forth a mammoth spring of good cool water. . . . . .

"The sub-carboniferous limestone makes its appearance at the base of the hills along this creek for a distance of several miles, and is overlaid by a few feet of shales and the massive sandstone at the base of the Millstone Grit. It also makes its appearance at the ore banks on Ore Branch of Richland Creek in section 28, township 7, range 4, and on the eastern border of the county line near the Virginia blast furnace along Richland Creek."

Professor Cox has probably mistaken the heavy sandstone above the middle limestone for the Millstone Grit (Mansfield sandstone), and has confused the limestones.

Ashley, in the coal report on Greene County[5], says:

"Lower Carboniferous.—The Kaskaskia is well represented in this county by limestone and sandstone, with some shales.

"The uppermost limestone, which is not very persistent here, usually is found but a few feet below Coal I or the equivalent horizon. This limestone, while often absent, attains a thickness of 20 feet in places. Then comes a variable thickness of sandstones and shales, and below that still heavier beds of limestone. The lower limit of the Kaskaskia is somewhat in doubt, as by some it is drawn at the top of this lower limestone, by others part way down it. The lower part of this limestone is probably of St. Louis age, and extends down into the Mitchell limestone."

Paragraph 1258[6]. Section at William Sexton's spring, S. W. of S. E. of Sec. 16-6-3. (C. E. S.)

1. Massive buff sandstone (Mansfield) 20
2. Heavy limestone (lower carb.) 14
3. Bluish gray shale 6

In the report on the road materials of Greene County, Blatchley says:* "Huron Limestone—The rocks of the Huron group lie close to the surface over the greater part of Greene County, east of White River. On the highest ridges and hills they are capped with the Mansfield sandstone. For the most part the exposed Huron rocks are also sandstone, but several localities there are outcrops of hard bluish Huron limestone, which appear well adapted for road improvement.

"The principal one of these exposures visited was on the land of George Cox, southwest quarter of the northwest quarter of section 3 (7 N., 4 W.). At this point the Indianapolis Southern Railway Company was constructing a viaduct 2,215 feet in length and 147 feet in height across Richland Creek, and a quarry had been opened to secure crushed rock for the concrete work in connection therewith. In this quarry the blue limestone was exposed in fourteen layers, each four to thirty inches in thickness, and aggregating seventeen feet. This limestone was both overlain and underlain with a Huron sandstone, the overlying portion being three to seven

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[5]Ashley, G. H., 23d Ann. Rept. Ind. Dept. Geol. and Nat. Res., 1898, p. 770, par. 1250.

[6] Op. cit. page 772.

* Blatchley, W. S., 30th Ann. Rept. Ind. Dept. Geol. and Nat. Res., 1905, p. 894.

feet in thickness, which, with a foot of soil, had to be stripped. The limestone appeared to be very hard and semi-crystalline in structure. . . .

"Another exposure visited was on the land of George Shipman, northeast quarter section 15 (7 N., 4 W.), where a quarry has been worked for macadam road material. At this point the blue Huron limestone was exposed to a thickness of fifteen to seventeen feet, with four to seven feet of buff Huron sandstone overlying. Sufficient material to cover six miles of road had been secured at this quarry, the supply in sight being practically inexhaustible.

"The same stone outcrops at many points along Beech Creek, and especially in section 12 (7 N., 4 W.), where it forms part of a great precipice or perpendicular bluff, 120 or more feet in height, the upper portion of which is a massive bed of Mansfield sandstone."

This latter is evidently the same exposure as that measured by Cox.

Shannon, in the report on the iron ores of Greene County[7], cites several instances of the replacement of limestone by iron as in section 6 below, but does ot discuss the stratigraphy.

From the foregoing it will be seen that very little work has been done on the stratigraphy or paleontology of the Chester in this area.

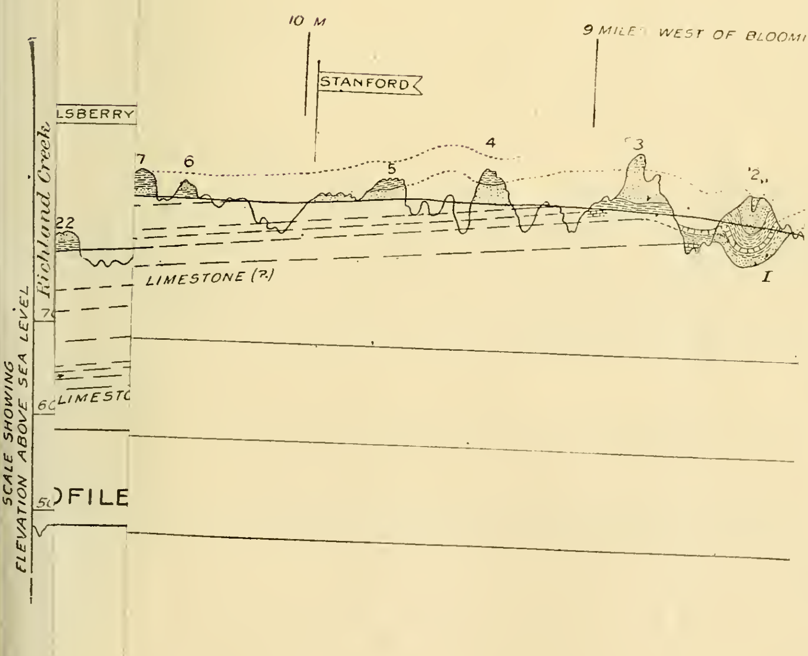
SECTIONS.

The following sections were obtained along the right of way of the Indianapolis Southern Railway, with the exception of Number IX, which was taken at the locality mentioned by Cox and Blatchley on Beech Creek, being about three-fourths of a mile south of VIII. The sections are shown on the profile.

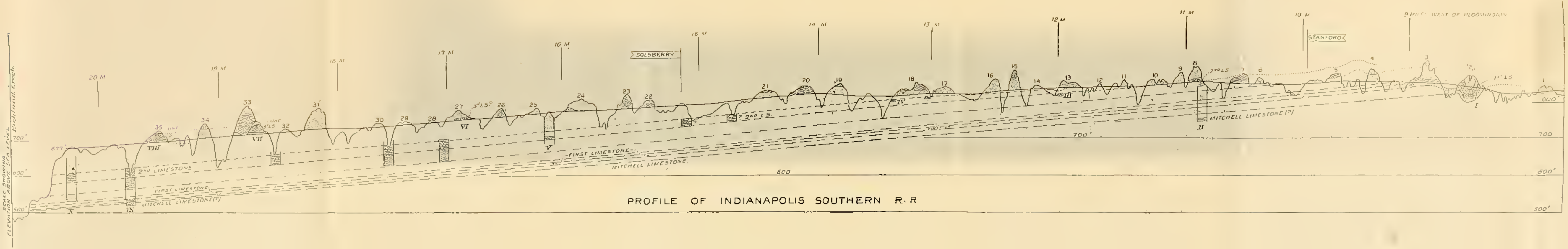
I.	5—Shale, sandy, and soil	15
	4—Sandstone, soft, reddish	22
	3—Shale, argillaceous, sandy in places and grading into sandstone at bottom	12
	2—Limestone, upper 2 in. oölitic and very fossiliferous, lower part with very few fossils beside foraminifera	2
	1—Shale, argillaceous, to track	10–12
II.	7—Sandstone, soft, ferruginous, cross-bedded	20
	6—Limestone, hard, fossiliferous, oölitic in places	6

[7] Shannon, C. W., 31st Ann. Rept. Ind. Dept. Geol. and Nat. Res., 1906, p. 373.

	5—Talus	3	
	4—Covered slope	30	
	3—Sandstone	17	
	2—Covered slope	27	
	1—Mitchell limestone (exposed)	5±	
III.	4—Sandstone in cut	10	
	3—Covered slope to track	10±	
	2—Limestone with spring at base	10	
	1—Covered slope to creek.		
IV.	4—Sandstone and shale, with thin coal and iron-ore (Pennsylvanian).		
	3—Covered	12–15	
	2—Limestone, exposed	4	
	1—Covered	4	
V.	4—Covered to level of track.		
	3—Sandstone	40	
	2—Covered slope	20	
	1—Limestone, spring at base—exposed	7	
VI.	3—Clay, shale and sandstone	24	6
	2—Iron-ore (replaced silicious limestone)		6
	1—Coal		6
VII.	4—Shale and sandstone, latter predominating	2	
	3—Sandstone, rather calcareous	1	6
	2—Shale, argillaceous or calcareous	12	
	1—Sandstone	0–5	
VIII.	17—Soil	4–5	
	16—Sandstone, thin-bedded	3–4	
	Unconformity.		
	15—Limestone, ferruginous, weathers to iron-ore		6
	14—Shale	4	
	13—Limestone, impure	3	
	12—Covered slope, fragmentary limestone and sandstone, but mostly shale	10	
	11—Limestone	1	6
	10—Shale		4
	9—Limestone like No. 7	1	



10 M
9 MILE WEST OF BLOOMI
STANFORD
LSBERRY
Richland Creek
22
7
6
5
4
3
2
I
LIMESTONE (?)
LIMESTO
SCALE SHOWING
ELEVATION ABOVE SEA LEVEL
FILE



PROFILE OF INDIANAPOLIS SOUTHERN R. R

	8—Shale, olive		6
	7—Limestone, hard		4
	6—Shale, olive		8
	5—Limestone, four layers, cross-bedded, hard crystalline, fossiliferous	3	
	4—Limestone, cross-bedded and brecciated	2	
	3—Shale parting with a limestone lens		0–10
	2—Limestone, hard, fossiliferous, brecciated, so-called "marble"	3	9
	1—Sandstone, shaly	2	6
IX.	7—Sandstone, even bedded	40 ±	
	6—Limestone	20	
	5—Shale, sandy or argill., weathers red in places	30 ±	
	4—Covered	25	
	3—Limestone, thin-bedded	5	
	2—Sandstone, thin intercalation		2–6
	1—Limestone, oölitic, probably Mitchell	10	
X.	3—Covered slope to track, sandstone in lower part and probably all sandstone	40	
	2—Limestone	17	
	1—Covered slope and sandstone to Richland Creek	90	

DISCUSSION OF STRATIGRAPHY.

When the attempt to unravel the stratigraphy of the group was begun, some trouble was encountered: (1) the unconformity which limits the group at the top; (2) the deposit of glacial drift in the area bordering Richland Creek; (3) the solution of the underlying Mitchell limestone on the eastern border, developing large folds and the collapse of strata; (4) solution of the limestone layers in the Solsberry formation; and (5) the fact that the Solsberry sandstones and shales have a tendency to be more or less cross-bedded and lenticular, as would be expected of a shore deposit. These factors detract somewhat from the correct interpretation of the stratigraphy.

Sections in the underlying Mitchell limestone in the region studied show that in most cases the top of the latter formation consists of a very typical white oölite, differing materially from that of the Chester. Ashley[8] noted the occurrence of oölite in the Mitchell limestone in many places; it has therefore been thought safe to consider this oölite, in the area studied, of Mitchell age, especially as the stratigraphic relations seem to confirm this view.

At 1[9], the Mitchell oölite is at the level of the track and is overlain by 8.5 feet of sandstone. West of this the Mitchell limestone forms the

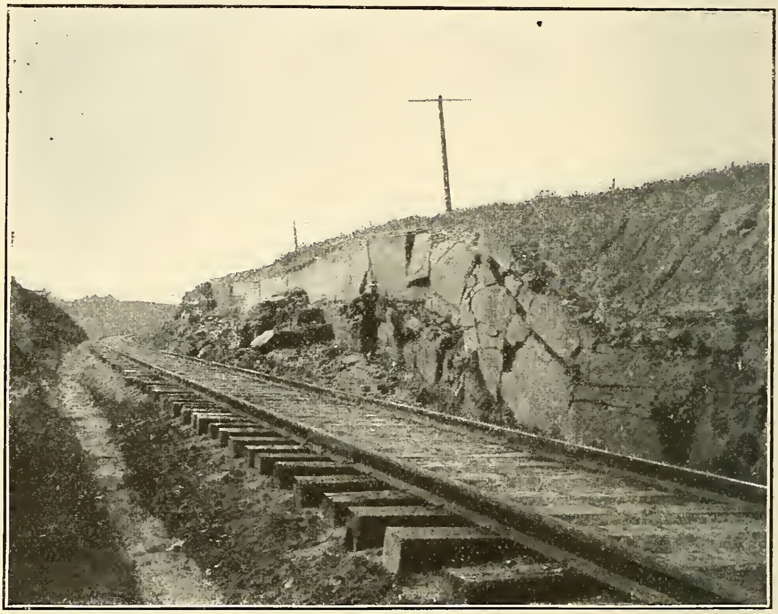


Fig. 1.

surface rock so that sinkholes are a conspicuous feature, but sandstone fragments are found. The relations of the strata at 2 have been greatly disturbed by the solution of the underlying Mitchell limestone so that a synclinal fold has been developed. Section I was taken at this point in the eastern part of the cut. The lower limestone, No. 2 of the section, has been dissolved to such an extent that only isolated blocks remain in the

[8] Ashley, G. H., Carboniferous Area of Southern Indiana, 27th Ann. Rep. Ind. Dept. Geol. and Nat. Res. 1902, p. 82.

[9] Numbers refer to cuts on accompanying profile section.

eastern part of the cut, while it has entirely disappeared from the western end. It is likely that the layer is thicker than two feet, as other exposures seem to show. The area between cuts 2 and 3 is a large compound sink. On the north side of the track, the Mitchell is found about thirty feet below, with ten feet of hard, light-colored sandstone overlying. On the south side, fifteen feet below the track, three feet of the lower limestone out-

Fig. 2.

crop. Shale occurs below it, but most of the section is covered. In cut 3 the following section was obtained:

4—Soil	6 ft.
3—Sandstone, ripple-marked and cross-bedded.............	31.5 ft.
2—Shale, blue, soft, clayey...............................	8–11 ft.
1—Limestone, lower, in ditch.	

In the eastern part of this cut the solution of the underlying Mitchell has again caused a synclinal folding of the beds. The shale No. 6 (of gen. sec.) first occurs in the top of the next cut 4 and continues in 5, 6, 7 and 8. It is a sandstone or arenaceous shale at the bottom, becoming more shaly in the middle and finally a clay shale at the top, in cut 8. From the exposures in cuts 4 and 5 it appears that a slight local unconformity may exist below this shale. In the eastern part of 8, the middle limestone first appears. Section II shows it to be 77 feet above the Mitchell as exposed in the valley below, which conforms with the dip and thickness of the underlying beds. This limestone appears at nearly every point west of cut 8, where its level is reached and its lower limit is marked by a spring

Fig. 3.

horizon. The correlation is based on stratigraphic, lithologic and paleontologic evidence and on the presence of springs in a few instances. It thickens progressively to the west, and on the east bluff of Richland Creek a quarry in it furnished rock for the railway viaduct. The cuts 8 to 21, inclusive, are in the upper sandstone with the exception of 18 and 20. This sandstone forms one of the prominent features of the topography. It is a reddish, ferruginous, laminated stone, appearing soft in the cuts but generally weathering into a hard bluff-forming stone where the drainage has cut through it. At places shale appears at the level of this sandstone.

These places may indicate lenses in the sandstone or shale of the overlying unconformable Pennsylvanian rocks.

At 18 the cut shows the unconformity and a mass of bog iron ore, coal and purplish-drab shale, resting on the sandstone only a few feet above the upper limestone. In cut 20 and the top part of 21, Pennsylvanian shale rests unconformably on the upper sandstone.

Fig. 4.

Between Solsberry and the viaduct, the railroad grade is about on a level with the top of the upper sandstone so that nearly all the cuts are in Pennsylvanian rocks. At 27, section VI was obtained. The iron ore (replaced limestone) of this section appears to be correlative with the upper limestone from stratigraphic and faunal evidence, which, however, is rather meagre. Coal occurs beneath it, while the sandstone above is probably of Pennsylvanian age.

Owing to the fact that it is replaced, only casts of shells remain, and in many cases these are unidentifiable. In view of this the correlation with the upper limestone must be tentative.

Section VII was obtained in the eastern part of cut 33, known as the "Head Cut." The western part of the cut is Pennsylvanian, an unconformity occurring about half way through the cut and above the upper limestone, so that the limestone may have been thicker than now exposed. This limestone is undoubtedly to be correlated with that in cut 35 (see section VIII) on stratigraphic and lithologic relations as well as faunal evidence.

Fig. 5.

The lower layers of the limestone in section VIII are brecciated and the limestones in both sections VII and VIII contain fragments of a sandstone similar to the underlying upper sandstone, while many species appear for the first time. The intervening cut, 34, contains sandstone, probably of Pennsylvanian age, and obscures the relations of cuts 33 and 35.

From the foregoing it will be seen that there is an apparent unconformity between the upper sandstone and limestone, which may account for the peculiarities of section VI.

The stratigraphic relation of the middle and upper sandstones and the middle limestones are easily determined, but there is some doubt as to the lower limestone and lower sandstone owing to the absence of exposures to the west. Section IX shows at the bottom of the slope, 15 feet of limestones, the upper 5 feet of which is thin bedded and contains fossils similar to the lower limestone in section I, except that the bryozoa are more conspicuous in the latter. The lower ten feet have a striking resemblance to the Mitchell limestone (oölite) both in appearance and fossil content, while between the two there is a thin intercalation of sandstone which is possibly the lower sandstone. The level of the rocks corresponds to the dip and thickness of the formation, but it is possible that the whole thickness belongs to either the Solsberry or Mitchell.

Fig. 6.

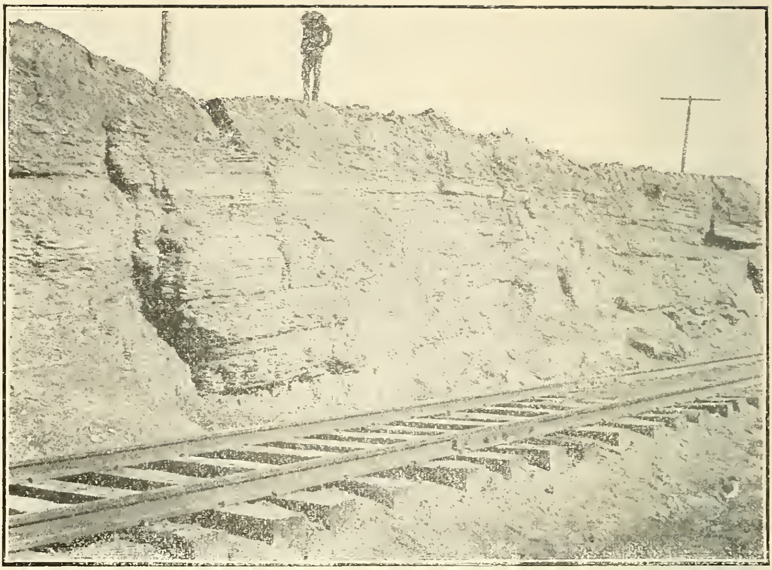


Fig. 7.

Fig. 8.

Fig. 9.

FAUNA.

The fauna of the limestones is rather large and well preserved, that of the sandstones and shale very meagre. The faunal lists follow[10]:

Lower limestone in section I.

Endothyra baileyi Hall.

Zaphrentis sp.

Echinocrinus sp.

Crinoidea 4 sp.

Batostomella abrupta ? Ulrich.

Fenestella sp.

Dielasma sp.

Productus burlingtonensis Hall. var.

Derbya sp.

Spirifer sp.

Martinia contracta M. & W.

Microdon subelliptica Hall.

Pelecypod sp.

Pleurotomaria subglobosa Hall.

Straparollus sp.

Strophostylus carleyana? (Hall) Keyes.

Loxonema yandellana Hall.

Solenospira attenuata (Hall) Ulrich.

[10] Prof. R. M. Bagg, of Illinois University, has kindly consented to examine the foraminifera of the collection, which appear to be rather abundant. At this time, his examination has not been completed and this important part of the fauna must be omitted.

Cyclonema leavenworthana Hall.
Bulimorpha buliformis Hall.
Microchelius stinesvillensis? Cummings.
Bellerophon sublævis Hall.
Orthonychia acutirostre (Hall) Keyes.
Leperdita carbonaria Hall.
Griffithides bufo? M. & W.

Mitchell ? limestone in section IX.
Hemitrypa ?? sp.
Polypora sp.
Martinia contracta M. & W.
Productus burlingtonensis Hall. var.
Dielasma turgida Hall.
Spirifer leidyi N. & P.
Derbya sp.
Bellerophon sublævis Hall.
Orthonychia acutirostre (Hall) Keyes.
Griffithides bufo M. & W.

Lower limestone in section IX.
Zaphrentis sp.
Crinoidea sp.
Streblotrypa nicklesi Ulrich
Cystodictya ocellata? Ulrich.
Intrapora undulata (Ulrich).
Stenopora tuberculata var. polymorpha Prout.
Fenestella tenax? Ulrich.
Fenestella sp. (reverse).
Batostomella abrupta Ulrich.
Rhombopora cf. nicklesi Ulrich.
Rhombopora sp.
Archimedes communis? Ulrich.
Bryozoa sp.
Martinia contracta M. & W.
Spirifer leidyi N. & P.
Spiriferina sp.
Productus sp.
Straparollus sp.

Middle limestone in section II.
Endothyra baileyi Hall.
Zaphrentis sp.
Pentremites pyrimidatus Ulrich.
Echinocrinus norwoodi Hall (spines).
Crinoidea 2 sp. (stems and calyx)
Lioclema? araneum Ulrich.
Rhombopora bedfordensis Cummings.
Rhombopora sp.
Fenestella serratula Ulrich.
Fenestella compressa Ulrich.
Fenestella sp.
Hemitrypa proutana Ulrich.
Fistulipora spergenensis ? Rominger.
Archimedes laxus? (Hall).
Polypora sp.
Dielasma turgida Hall.
Dielasma formosa Hall.
Martinia contracta M. & W.
Seminula trinuclea Hall.
Spirifer leidyi N. & P.
Derbya keokuk Hall.
Productus burlingtonensis Hall. var.
Productus parvus? M. & W.
Productus cora? D'Orbigny.
Cypricardinia indianensis Hall.
Microdon subelliptica Hall.

Nucula shumardana Hall.
Productus cestriensis Worthen.
Conocardium meekanum Hall.
Myalina? sp.
Pelecypod sp.
Pleurotomaria? wortheni Hall.
Pleurotomaria? subgolbosa Hall.
Loxenema yandellana Hall.
Straparollus similis M. & W.
Straparollus spergensis (Hall).
Straparollus sp.
Stropostylus carleyana Hall.
Cyclonema subangulata Hall.
Cyclonema leavenworthana Hall.
Solenospira turritella (Hall) Ulrich.
Solenospira vermicula (Hall) Ulrich.
Solenospira sp.
Bulimorpha caniculata Hall.
Bulimorpha? sp.
Holopea proutana Hall.
Bellerophon sublævis Hall.
Orthonychia acutirostre (Hall) Keyes.
Bairdia cestriensis Ulrich.
Cytherella ovatiformis Ulrich.
Griffithides bufo M. & W.
Fish 3 sp. (teeth).

Middle limestone in section III.

Fenestella serratula Ulrich.
Fenestella c. f. multispinosa Ulrich.
Anisatrypa solida Ulrich.
Archimedes sp.
Martinia contracta M. & W.
Dielasma formosa Hall.
Productus parvus ? M. & W.
Productus cestriensis? Worthen.
Productus cora? D'Orbigny.
Spirifer leidyi N. & P.
Griffithides bufo M. & W.

Middle limestone in section IV.

Endothyra baileyi Hall.
Martinia contracta M. & W.
Bellerophon sublævis Hall.

Middle limestone in section V.

Fenestella sp.
Martinia contracta M. & W.
Productus cestriensis? Worthen
Bellerophon sublævis Hall.

Middle limestone in section X.

Pentremites pyrimidatus Ulrich.
Crinoidea sp.
Archimedes sp.
Productus cestriensis Worthen.
Productus sp.
Spirifer leidyi N. & P.
Martinia contracta M. & W.

Upper ? limestone in section VI.

Zaphrentis spinulosa? M-E. & H.
Crinidea 3 sp. (segments).
Pentremites sp. (one poral plate).
Stenopora sp.
Fenestella cestriensis Ulrich.
Fenestella 2 sp.
Coeloconus rhombicus? Ulrich.
Polypora spinulifera Ulrich.
Archimedes sp.
Spirifer leidyi N. & P.
Derbya kaskaskiensis? Hall.
Dielasma turgida Hall.
Spiriferina spinosa N. & P.

Eumetria marceyi Shumard.
Productus parvus? M. & W.
Productus cestriensis? Worthen.
Productus cora? D'Orbigny.
Orbiculoidea sp. (cast).
Brachiopod sp. (cast).
Pleurotomaria sp. near tabulata Conrad.
Pleurotomaria sp. (cast).
Straparollus sp. (cast).
Bellerophon sublævis Hall.
Orthonychia chesterense ? M. & W.
Gastropod sp. (cast).
Bulimorpha sp. (cast).
Pleurophorus minimus Worthen.
Pleurophorus sp.
Microdon sp.
Nucula parva McChesney.
Modiala illinoisensis Worthen.
Schizodus ? sp.
Aviculopecten sp.
Pelecypoda 5 sp. (casts).
Primitia subæquata Ulrich.
Psammodus sp. (cast of tooth).
Cladodus spinosus ? M. & W. (cast of tooth).

Upper limestone in section VII.
Pentremites godoni DeFrance.
Pentremites florealis Schlotheim.
Pentremites pyriformis Say.
Pterotocrinus depressus Lyon and Cassiday (wing plates).
Acrocrinus shumardi Yandell.
Hydreionocrinus armiger M. & W.
Crinoidea 6 sp. (plates and segments).
Echinocrinus sp.
Thamniscus furcillatus Ulrich.
Fistulipora excelens? Ulrich.
Stenopora tuberculata Prout.
Stenopora rudis Ulrich.
Lioclema araneum Ulrich.
Coeloconus rhombicus Ulrich.
Fenestella flexuosa Ulrich.
Fenestella tenax Ulrich.
Fenestella cestriensis Ulrich.
Fenestella multispinosa? Ulrich.
Fenestella elevatopora? Ulrich.
Fenestella 2 sp.
Polypora cestriensis Ulrich.
Septopora subquadrans Ulrich.
Streblotrypa nickelsi Ulrich.
Batostomella spinulosa Ulrich.
Rhombopora minor Ulrich.
Rhombopora tenuirama Ulrich.
Rhombopora sp. near tabulata Ulrich.
Archimedes meekanus? Hall.
Ptilipora pauperi ? Ulrich.
Seminula trinuclea Hall.
Eumetria marceyi Shumard.
Cleiothyris sublamellosa? Hall.
Spiriferina spinosa N. & P.
Spirifer leidyi N. & P.
Productus parvus M. & W.
Dielasma turgida Hall.
Reticularia setigera Hall.
Trilobite sp.

Upper limestone in section VIII.
Zaphrentis spinulosa M-E. & H.
Pterotocrinus depressus Lyon and Casseday.
Hydreionocrinus armiger M. & W.

Crinoidea sp. (segments).
Pentremites sp.
Rhombopora sp. near tabulata Ulrich.
Rhombopora sp.
Stenopora sp.
Fenestella cestriensis? Ulrich.
Fenestella flexuosa Ulrich.
Fenestella sp.
Polypora spinulifera Ulrich.
Polypora cestriensis Ulrich.
Lioclema araneum Ulrich.
Streblotrypa nicklesi Ulrich.
Fistulipora excelens? Ulrich.
Archimedes distans Ulrich.
Archimedes sp.
Dielasma sp.
Productus sp.
Spiriferina transversa McChesney.
Spiriferina spinosa N. & P.
Spirifer leidyi N. & P.
Eumetria marceyi Shumard.
Brachiopod sp.
Aviculopecten c. f. monroensis Worthen.
Orthonychia chesterense M. & W.
Spirorbis c. f. imbricatus Ulrich.
Griffithides granulatus Wetherby.
Cladodus sp. (base of tooth).
Fish sp. (spine).

Discussion of fauna. From the foregoing lists, it will be seen that the fauna of the lower and middle limestones have many of the elements of the Salem fauna. This is particularly true at the eastern extensions of these beds where, in all probability, the shallow, lagoonal conditions favorable to this fauna, prevailed.

The lower limestone in section I has only two species which do not occur in the Salem limestone. These are *Martinia contracta* and *Batostomella abrupta*? The latter was not found in the middle limestone. The western extension of the lower limestone retains a few of the Salem species but indicates a condition of deposition farther from the shore-line. To the west it also contains *Batostomella abrupta.* In the collections from the lower layer, foraminifera are very scarce.

Collections from the middle limestone show that many Salem species continued to exist, but *Martinia contracta* is the most noticeable species, and *Pentremites* becomes a prominent member of the fauna. Thin sections from this horizon show under the microscope a great number of forms of foraminifera, and will undoubtedly yield many species, an element which will distinguish this limestone wherever found.

The faunal character of the upper limestone is entirely distinct from that of the two lower layers. It is of late Chester age and shows no distinct Salem forms.

If the limestone in section VI is to be correlated with the upper limestone, it shows what is probably a littoral phase of the layer, which to the west shows only deep water conditions.

CONCLUSIONS.

To briefly summarize, the Chester or Huron formation of western Monroe and eastern Greene counties consists of three limestones with separating sandstone and shale.

Dr. E. O. Ulrich, of the United States Geological Survey, has examined the lists of fossils given herewith and expressed the opinion that they represented the greater part of the Chester of Kentucky and southern Illinois. As the stratigraphy seems to confirm this, the following correlations are made:

Chester Group.	Upper (third) limestone. Upper sandstone.	Birdsville formation.	
	Middle (second) limestone.	Tribune Limestone.	
	Middle sandstone.	Cypress sandstone.	
	Lower (first) limestone. Lower sandstone. Oölitic upper portion of Mitchell.	Ohara limestone member. Rosiclare sandstone member. Fredonia oölitic member.	Ste. Genevieve Formation.
Remainder of Mitchell.		St. Louis limestone.	

The line of division between the St. Louis and the oölitic above has not been located in Indiana, but the latter is probably at least 30 feet thick.

Determination of the Ratio of Specific Heats of Dry Air.

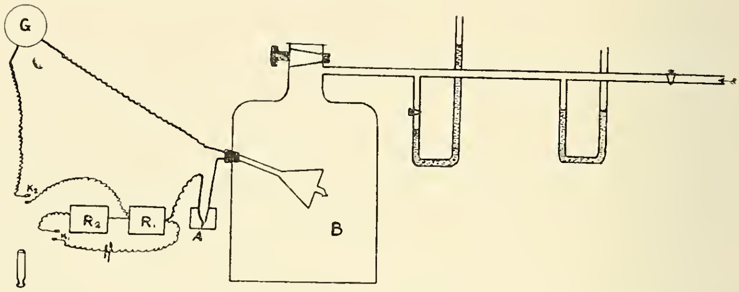
E. K. Chapman.

The following method for determining the ratio of specific heats was suggested by some work in connection with an experiment in a fog chamber. It became necessary to know the temperature in a fog chamber on sudden expansion and consequent condensation of vapor. In order to measure this temperature a thermo-couple of Cu and Fe was introduced, and the deflection of a galvanometer connected in series with the couple was noted on the expansion of the saturated vapor. The couple was then graduated by keeping one junction at a constant temperature and noting the deflection of the galvanometer for a given change in temperature of the other junction. Knowing, then, the constant of the apparatus, the temperature in the fog chamber was easily determined.

The attempt was then made to use this method for finding the temperature in a chamber of air on sudden expansion, and thus determine the ratio of the specific heats.

To the stopper of a glass carboy was fitted a large valve that could readily be opened or closed by hand. One junction of the thermo-couple was introduced into the carboy through a rubber stopper fitted in a hole drilled in the side. The inner ends of the bent tube carrying the couple were then separated by twisting the tubes in the rubber stopper. The other junction was encased in a small glass bulb just outside the bottle and this kept at a temperature of the surrounding medium. Later in the work the entire apparatus, excepting the valve, was immersed in a bath which could be maintained at a constant temperature. Dry air was then pumped into the bottle and the whole was allowed to stand until it had regained the temperature of the surroundings. On opening the valve the temperature falls, due to the adiabatic expansion, and the galvanometer is deflected because of the difference in temperature of the two junctions of the couple. From this deflection it was hoped that the lowest temperature in the chamber might be calculated. A great deal of difficulty was experienced in trying to calibrate the couple, since the deflections due to a given difference in temperature varied considerably, and the degrees of accuracy desired necessitated a more consistent calibration. After repeated efforts to obtain a constant deflection for a given difference in temperature the method was abandoned as not being sufficiently accurate.

The following scheme was then adopted:



A battery of known E. M. F. was connected in series with two resistances, R_2, which was approximately 100,000 ohms, and in later experiments kept constant, and R_1 was varied from one to eight ohms to suit the conditions of the particular observation. B is a carboy in the center of which one junction of the couple was located. A is a second junction which was kept at a constant temperature. G is a galvanometer in series with the couple and R_1. The air in B was compressed as before and allowed to cool to the temperature of the bath. K_1 was then closed, then the valve was opened to the atmosphere and immediately K_2 was closed and the direction of the deflection of the galvanometer noted. This process was repeated, varying R_1 until a resistance was found such that on closing K_2 there was no deflection of the galvanometer, until the air began to warm after the adiabatic expansion. This balanced condition meant that the P. D. across R_1 just balanced that due to the difference in temperature of the two junctions of the thermo-couple.

In practice it was found better to set R_1 at a given place, e. g., 5 ohms, and then vary the original pressure until a balance was obtained. In some of the earlier observations R_2 was varied to secure a balance, but since it was not known to a sufficient degree of accuracy, the other method was used. It then remained to calibrate the thermo-couple. This was done by placing one junction, encased in a jacket, in a constant temperature bath, and the other, similarly encased, in a bath whose temperature was varied till a balance against a given resistance, R_1, was obtained. The difference in temperature of the two junctions was then noted. R_1 was again varied and the temperature of the bath changed until another balance was found. In this way a number of balances were obtained for different values of R_1. By plotting R_1 against the difference in temperature of the two junctions a curve was obtained which gave the temperature for any resistance. The calibration was made with a number of different couples and the results were entirely consistent, no point being off the straight line thus found more than 1-20 of a degree centigrade.

The pressure in the bottle was measured by means of an oil manometer: as considerable time was consumed by the oil coming to a steady state, it was deemed desirable to place a stopcock between the manometer and the bottle, and after the pressure was determined cut off the manometer before expansion. The pressure for the following trial was adjusted approximately by an auxiliary mercurial manometer and the final adjustment was made with oil. The use of the oil manometer was necessary, as the errors introduced in the reading of the mercurial manometer were of a higher degree of magnitude than was permissible.

The delicacy of the apparatus was indicated by the fact that the observer could readily detect a difference in pressure of 2 mm. of oil, density .84.

The value of γ was determined as follows:—

From the adiabatic law, $P V\gamma$ = a constant

From the law of Charles, $PV = RT$

or $P_1V_1\gamma = P_2V_2\gamma$

then $$\left(\frac{V_2}{V_1}\right)^\gamma = \frac{P_1}{P_2}$$

but $P_1V_1 = RT_1$

and $P_2V_2 = RT_2$

$$\frac{V_2}{V_1} = \frac{P_1}{P_2} \quad \frac{T_2}{T_1}$$

$$\left(\frac{V_2}{V_1}\right)^\gamma = \left(\frac{P_1}{P_2} \quad \frac{T_2}{T_1}\right)^\gamma = \frac{P_1}{P_2}$$

therefore $$\gamma = \frac{\log \frac{P_1}{P_2}}{\log \frac{P_1}{P_2} - \log \frac{T_1}{T_2}}$$

The following table gives the results of the experiment:

P_2	θ_1	R_1	R_2	A	B	A—B	P_1	θ_2	γ
74.14	294.—	2.2	100100	94.6	25.-	69.6	78.44	289.4	1.3888
75.26	294.05	2.2	100100	95.9	24.-	71.9	79.70	289.35	1.3910
74.72	294.2	2.1	109500	89.5	30.-	59.5	78.39	290.34	1.3803
74.5	293.9	2.1	103800	89.7	30.-	59.7	78.19	289.81	1.4802
75.19	293.95	2.1	103800	90.9	29.2	61.7	79.—	289.71	1.4160
75.49	293.1	3.2	100300	145.-	46.4	98.6	81.58	286.6	1.4042
74.99	293.7	3.2	100500	145.-	47.-	98.-	81.04	287.47	1.3872
74.99	293.5	3.2	100500	144.7	46.3	98.4	81.07	287.1	1.3945
75.06	293.6	4.7	101200	169.-	22.1	146.9	84.14	284.3	1.3927
74.84	294.1	4.7	100700	170.-	21.8	148.2	84.00	284.51	1.4027
75.52	293.8	4.-	100000	158.1	33.6	124.5	83.21	286.2	1.3704
74.76	"	5.-	"	174.2	18.2	156.2	84.41	283.89	1.3938
74.76	"	4.-	"	159.0	33.5	124.5	82.45	285.81	1.3921
74.76	"	3.-	"	142.0	50.-	92.-	80.44	287.81	1.3911
74.71	"	6.-	"	195.-	7.-	188.-	86.33	281.96	1.3974
74.71	"	6.-	"	195.-	7.-	188.-	86.33	281.88	1.4013
74.57	"	5.-	"	178.5	29.3	154.6	84.12	283.86	1.4001
74.57	"	4.-	"	162.1	40.3	121.8	82.09	285.84	1.3997
74.57	"	3.-	"	146.5	57.3	89.2	80.08	287.84	1.4040
74.57	"	2.-	"	132.5	73.7	58.8	78.20	289.83	1.4005
74.44	293.82	1.-	"	118.2	88.8	29.8	76.25	291.83	1.3925

Average.......................1.3957
Av. for last 10.................1.3973

P_2 is the reading of the barometer. θ_1 is the original temperature of the bath. A and B readings of the oil manometer. $P_1 = P_2$ (A—B) d_1/d_2 where d_1 = density of oil and d_2 = density of mercury. θ_2 is the temperature as given by the thermo-couple required to secure a balance.

γ = ratio of specific heats.

DISCUSSION OF RESULTS.

The limits of precision seem to be the precision of the resistance, the precision of the temperature reading as read by a thermometer, the precision of the temperature readings used to calibrate the couple, the consistency of the E. M. F. of the battery and the density of oil.

The precision of the resistance was none too good. The last ten observations were made with the best box available and R_2 kept constant so that errors due to R_2 were obviated. The maximum variation of the mean of these observations is less than ½ per cent., and shows remarkable constancy.

A new storage battery "duro," made by the Chicago Battery Co., was used and showed no variations in E. M. F. during the entire time.

The density of the oil was determined by a specific gravity bottle and found to be .8370.

The temperatures were read on a standard thermometer graduated to 1-10 degree.

As to the question of the accuracy of the thermo-couple in registering the instantaneous temperature we have to consider the couple itself, its behavior under known conditions, and the results obtained.

The couple was of Fe-Cu, one millimeter in diameter, so its heat capacity was very small. In calibrating it a deflection was regularly noted when the change of temperature of the bath was less than 1-100 of a degree. It was found that for small changes in temperature considerable time, several seconds, elapsed before there was any heating due to radiation, etc. This was due largely to the size of the vessel. Using a smaller one the time required to warm up was small.

The experiment is now being repeated under vastly better conditions. The temperature of the bath is regulated by an electric thermostat, the resistances, barometer and thermometer, have been checked up by the Bureau of Standards at Washington and the voltage of the "duro" cell tested immediately before and after each observation, by means of a potentiometer of the Leeds Northrup type and a standard Weston cell. The results from the new determination will be published later.

Wabash College,

Crawfordsville, Ind.

A Convenient High Potential Battery.

By R. R. Ramsey.

In work on radioactivity it is necessary to have a battery whose potential is 100 volts or more. If one has access to a direct current lighting circuit a storage battery made of test tubes with sheet lead strips for electrodes can be used. Fifty such cells arranged in a rack make a convenient battery when the lighting circuit is 110 volts. Such a battery requires a week or more for forming, and due to the small capacity of the cells they should be connected to the charging circuit all the time except when in actual use. When it is not convenient to make such a battery, or when the facilities for keeping it charged are not at hand, I have found that a battery can be made with little trouble and expense of tubular flash lamp batteries. The so-called 3½ volt flash lamp batteries consist of three small dry cells slipped into a pasteboard tube. The bottom of the cell is the negative terminal, while the central carbon has a projection extending through the top, which serves as the positive terminal of the cell. Thus the three cells when placed in the tube are in series. If the cells are slipped down through the tubes until the bottom ones project one-half their length the batteries can be placed one on top of another and form a long battery connected in series, the potential of which depends upon the length. The so-called 3½ volt battery when new has an E. M. F. of about 4.4 volts. Or twenty-five such batteries in series give 110 volts. Of course it is not necessary to connect all in one "stick." They can be placed in "sticks" of convenient length and placed upright in a box and connected in series by soldering wires to the ends, thus making connections which will give intermediate potentials. When new these batteries have very low resistance, and great care should be exercised to prevent short circuiting the cell. Like all dry cells the resistance increases with age and the potential at the terminals as shown by a voltmeter will decrease. But the E. M. F. of the cells as shown by potentiometer measurements remains constant until the cells are completely dried out. Since the battery in radioactivity work is used for static potentials the high internal resistance of the cells will not cut any figure.

These batteries can be obtained from the electrical supply houses at 20 cents apiece. Thus a 110 volt battery will cost $5.00.

Physical Laboratory,

Indiana University, April 11, 1911.

The Equipment of a High Temperature Measurement Laboratory.

By G. A. Shook.

MEASUREMENT OF HIGH TEMPERATURES.

The first attempt to measure temperatures with any accuracy seems to be due to the celebrated potter, Wedgewood, although he was not the first by any means to recognize the importance of temperature estimation and temperature control in kilns in order to reproduce a given effect. In the time of the Romans the working of iron had undoubtedly reached an advanced stage, but their methods and knowledge of the metallurgy of iron were entirely empirical. In the eighth century a writer, in outlining a method for obtaining high temperatures, called attention to the most difficult part of the problem, namely, that "fire is not a thing which can be measured." Even within recent years the temperature of a steel kiln was not known within 500 degrees C. and the values given for the temperature of the sun ranged from 1,500 to 1,000,000 degrees C. Today, however, with our advanced methods of radiation pyrometry, the student of physics can measure the temperature of the sun, the highest known temperature, with as much ease and accuracy as he can determine the specific heat of a piece of lead.

It has been known for several years that numerous industrial processes, carried out at high temperatures, require a temperature control of 20 degrees C. Mr. C. E. Foster[1], in speaking of the successful production of finished castings, remarked that there are four main factors to be considered:

1—Composition of the material melted.

2—Atmosphere and surroundings.

3—Temperature.

4—Time.

The first two of these are taken care of by the chemist, but the third and fourth must be controlled by the man trained in pyrometry. It requires but a casual glance through the trade journals to convince one that the

[1] The Foundry, May, 1909.

men who are handling this problem in the industries are not sufficiently trained to appreciate the limitations of its practical application. Therefore the engineer or chemist must be trained along this line if he expects to do the most efficient work. High temperatures were, until quite recently, estimated by the trained eye of a workman, and while they acquired with practice a surprising accuracy, such a procedure is entirely inadequate for present day requirements. Moreover, the observer's estimate is influenced manifestly by a number of circumstances, such as the amount of light in the room, fatigue of the eye, physical condition of the observer, etc. The greatest disadvantage is that a skilled workman in Pittsburg can not gain anything from the experience of a workman in Birmingham. In times past numerous methods have been devised and used for temperature estimation and temperature control, but the temperature scales used were so discordant that about six years ago the Bureau of Standards[2] made a thorough investigation of the most available methods.

There are today four precise laboratory methods for measuring high temperatures, each of which is the basis of an industrial pyrometer:

Electric-resistance Pyrometer.—In this pyrometer use is made of the variation of the electric resistance of metals with change of temperature. Since resistance can be measured with extreme precision this method permits of very precise measurements of temperature up to 1000° C.

Thermoelectric Pyrometer.—This instrument utilizes the variation of the electromotive force with temperature, developed at the junction of two dissimilar metals. This pyrometer may be used for temperatures up to 1600° C. when the thermo-couple consists of wires of platinum and platinum-rhodium or iridium.

Radiation Pyrometer.—In this type of pyrometer the total radiation from hot bodies is taken as a measure of their temperature. This instrument requires a device for determining very small changes in temperature, and does not admit of very great accuracy, but is very convenient for very high temperatures.

Optical Pyrometer.—In the case of pyrometers of this class temperature estimation is made by means of a photometric comparison, for a particular wave length, between the radiation from some standard lamp and the radiation emitted from the body under observation. This is a very precise method and is available for the highest known temperature.

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[2] Bulletin Bureau of Standards, Vol. 1, p. 189.

TEMPERATURE SCALE.

The usual method of measuring temperature is by the expansion of some substance, such as mercury in the ordinary glass thermometer, or gas in the more refined work. With such a method, however, the magnitude of a degree will depend upon the nature of the substance employed, which is undesirable in scientific work. A theoretical thermometric scale, independent of any substance used, has been worked out by Lord Kelvin and is known as the "Thermodynamic Scale." Temperatures on this scale are measured by the work done in carrying a substance around a Carnot's cycle working between two sources at constant temperature.

Without attempting any proof here, the theory gives the following relation,

$$\frac{T_1}{T_2} = \frac{Q_1}{Q_2}$$

where T is the absolute temperature and Q is the quantity of heat, which can be measured in terms of energy since by the first law of thermodynamics heat is proportional to work. Hence the ratio of any two temperatures may be determined from purely mechanical considerations and will furthermore be independent of the substance used in the conversion of work into heat. Experiment has shown, however, that no known gas is perfect, and that, furthermore, no gas is satisfactory throughout the entire range of temperatures which are used in gas thermometry.[3] The practical standard is the international Normal Scale of the constant volume hydrogen thermometer. Hydrogen can be used for very low temperatures, but above 300° C. it is unreliable. Nitrogen, on the other hand, can not be used for low temperatures, but is suitable for high temperatures. In the absence of a perfect gas we have practical standard gas thermometers, such as hydrogen and nitrogen, for which thermodynamic corrections have been determined. In practice, however, the gas thermometer is never employed by reason of the difficulties inherent in its use and, furthermore, because there are numerous other thermometers more convenient which can be compared with the gas thermometer.

In exact work, it is necessary, therefore, to define temperature in the terms of the thermodynamic scale rather than the "Normal" or "Gas Scale." Especially is this true in the case of radiation pyrometry, where the laws and formulas developed have their foundation in the second law

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[3] Bulletin, Bureau of Standards, Vol. 3, p. 237.

of thermodynamics. Consequently the "temperature" which occurs in the equations is the absolute thermodynamic temperature.

The standardization of pyrometers is generally made by means of certain fixed points, such as the fusion of platinum, palladium, gold, etc., and the ebullition of water, aniline, naphthaline, sulphur, etc., which have been carefully determined by means of the gas thermometer. The platinum thermoelectric pyrometer, on account of its ease of manipulation, convenience, and accuracy, has come into general use for temperature measurements between 1200° C., the upper limit of the gas thermometer, and 1600° C. The thermo-couple may be directly compared with the gas thermometer up to 1200° C., but beyond this we must rely on extrapolation up to 1600° C., which is the limit of the thermo-couple. Beyond this range, the scale must depend upon radiation laws which have some theoretical support and can be tested within the range of the gas scale.

It is seen from the above that high temperature measurements may be made in terms of the thermodynamic scale, but that the actual precision is entirely subordinate to that of the various intermediate steps, which lead from the perfect gas thermometer to the radiation pyrometer.

APPARATUS.

Electric-resistance Pyrometer.—Pyrometers of this type are more or less familiar to persons who have had any experience whatever in Heat or Electrical Measurements' laboratories. To illustrate the application of resistance thermometry, in the laboratory, a number of pure metals such as nickel, iron, silver, and copper may be used for temperatures up to 300° C., and there are several types of cheap, compact, serviceable instruments now on the market. For practical use and calibration the coil of wire used should be inclosed in a tube or stem of some suitable material, such as glass, iron, or porcelain, depending upon the temperature to which it is subjected. This stem should terminate in a head provided with binding post for making connections to lead wires. As the resistance of the lead wires will vary with the depth of immersion it is necessary to provide compensating leads which are put in the adjacent arm of a Wheatstone bridge. For all temperatures, from the lowest obtainable up to 1000° C., and especially for the higher temperatures, platinum[4] is the most satisfactory. When used for high temperatures (up to 1000° C.) the platinum coil is generally wound over a mica frame and inclosed in an infusible porcelain stem.

Thermoelectric Pyrometer.—Numerous materials have been used around the laboratory for thermo-couples, but the cheapest and at the same time the most reliable is the copper-constantan. The latter metal is known in this country as Advance, or Ia Ia. This couple can be used up to about 900° C. An extended investigation of this thermoelement has been carried out by White,[5] who recommends it as a precision thermometer. For temperatures between 300° C. and 1600° C. platinum and some alloy of platinums must be used.

The choice of a couple depends entirely upon the conditions under which it is to be used. For high temperatures the platinum couple (Pt——Pt + 10%Rh) is perhaps the only one that is used with success, but for low temperatures, say up to 1000° C., a number of alloys are used in industrial processes with good success. For low temperatures it is necessary to choose metals that will produce a higher P.D. than that used at high temperatures. For temperatures below 100° C., the couple may be calibrated by direct comparison with mercury thermometer, but for high temperatures fixed points are necessary.

The method of measuring the P.D. depends upon the accuracy required. For precise work the cold junction should always be kept at constant temperature (generally melting ice) and the P.D. should be measured on a potentiometer, using a standard cell. For work when great precision is not necessary, a d'Arsonval galvanometer or even a sensitive millivoltmeter is sufficiently accurate. In industrial practice the outfit must be as portable and compact as possible so that a direct reading instrument is generally used, which is substantially a millivoltmeter calibrated to read direct in temperature °C. or °F. The cold junction in such cases is generally maintained at 25° C. or 75° F., and the instrument is calibrated to be correct at that temperature. Any slight variation will not cause a great error, but an approximate correction can always be made by adding to the indicated temperature the difference between the temperature of the cold junction and 25°, when the former exceeds 25°, and subtracting the difference when it is less than 25°. Correction can also be made by means of an automatic

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[4] Bulletin Bureau of Standards, Vol. 6, p. 149.

[5] Phys. Rev., Aug., 1910, p. 135.

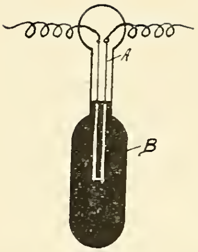

Fig. 1.

compensator as shown in Fig I. It consists of a fine platinum wire A, which is partially immersed in mercury B. When the bulb is heated the mercury in the capillary tube expands and short circuits the platinum loop, thus diminishing the resistance of the circuit. This balances a change in e. m. f., due to a rise of temperature of the cold junction.

All the contacts of the different parts of the circuit should be carefully made, and wherever possible this should be done by soldering. The hot junction of the wires used in the couple should be fused together. For easily fusible metals, such as copper, this can be done in the Bunsen flame, but for platinum oxygen is required. Platinum may also be fused in the electric arc. At the cold junction the lead wires should be soldered to the thermo-element wires. The wires composing the couple, which are subjected to high temperatures, should be insulated throughout their entire length by glass tubes or pipe stems. Asbestos thread may also be used for temperatures below 1300° C. Small fire clay tubes pierced by two holes may also be procured and are very convenient. For industrial work the couple should be inclosed by an iron or porcelain tube. The former should not be used for temperatures over 800° C.

Radiation Pyrometry.—From the fact that the intensity of light emitted from a body increases very rapidly with rise of temperature the optical method is well adapted to the measurement of high temperatures. For example, the luminous intensity of the red part of the light emitted by a body of 1500° C. is 130 times the intensity of 1000° C., and at 2000° C. it is more than 2100 times as great as at 1000° C. It thus appears that a comparatively rough measurement of the luminous intensity of an incandescent body would give a pretty accurate measurement of its temperature. This conclusion, however, is modified by the fact that different bodies at the same temperature emit very different amounts of radiant energy. The radiating power of a body depends not only upon the temperature but also the composition and nature of the surface. In order that the radiation and optical methods can be used for comparison of temperatures it is necessary that the effect of differences of surfaces be eliminated. This can be done by reducing the radiation from all surfaces to the radiation that would occur from some ideal surface arbitrarily taken as a standard of comparison.

A body that would absorb all the radiant energy incident upon it is called a perfectly black body. From a consideration of Prevost's theory of exchange it can be shown that a body inside an inclosure all parts of which are at the same temperature is a perfectly black body. Kirchoff has shown that the radiation from a perfectly black body depends only upon its temperature. For this reason the radiant energy emitted by a perfectly black body is taken as the basis for the comparison of high temperature. Radiation and optical pyrometers are calibrated by comparing a series of actual temperatures of a perfectly black body with the amounts of energy radiated at the respective temperatures. Two bodies are at the same black body temperature when they emit equal amounts of radiant energy. Two bodies at the same actual temperature, determined by means of a gas thermometer, will not be at the same black body temperature unless their surfaces have the same radiating power. For example, a piece of iron and a piece of porcelain each at an actual temperature of 1200° C., if examined by means of an optical pyrometer calibrated in terms of the red rays emitted by a perfectly black body, would indicate 1140° C. and 1100° C. respectively. If, however, two bodies be placed inside a uniformly heated inclosure they will not only attain the same temperature, but they will also emit radiant energy equally. That is, they will have the same black body temperature. In other words, the actual temperature of a body inside a uniformly heated inclosure equals the black body temperature.

A pyrometer then, which has been calibrated by comparison with a black body, when sighted upon an incandescent body, reads not its true temperature (thermodynamic temperature), but its black body, which will be somewhat lower than its true temperature. The difference will depend upon the emission power of the body. If, however, the body sighted upon is a black body, for example a heated inclosure, then the pyrometer indicates its true or thermodynamic temperature. A few substances such as platinum black, carbon and iron oxide radiate approximately as black bodies, but as yet there is no known substance which is absolutely black. In using the term in this sense we must remember that the temperature must be involved as well as the emission and absorption powers. Thus, any body whose radiation is proportional to that of a black body, for all wave lengths, is considered *black* if its temperature is the same as a black body. If its true temperature is higher (it could never be lower) it is considered *gray*. A carbon lamp filament is gray because its spectral distribution is the same as a black body, but not black because its true temperature is slightly higher than a black body.

A uniformly heated inclosure is the nearest approximation to our ideal black body.

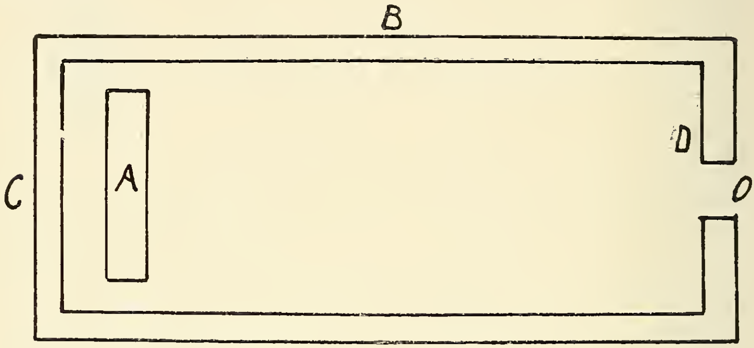

Fig. 2.

Consider a body A within a heated inclosure B, Fig. 2, both at the same temperature throughout. A receives a certain amount of thermal radiation from the wall of the envelope C and radiates to C an equal amount if they are in temperature equilibrium. Also A radiates a certain amount to D and receives the same amount, if D is at the same temperature. Since A, on the whole, neither gains nor loses it radiates to D the same amount it receives from C, consequently the radiation from A towards D is the same as that from C towards D. Not only is the quantity the same but also the quality, for the coefficient of absorption depends upon the quality (i. e., it is different for different parts of the spectrum), so that if C and A radiate the same amount they must radiate the same quality. If the spectral distribution of A were different from C its coefficient of absorption would be different and therefore it would not radiate the same quantity. Hence any other body within B and at same temperature would radiate the same as A so that no detail could be detected, i. e., the objects could not be distinguished from one another or the walls of the inclosure.

Moreover any body outside of B at the same true temperature could not radiate more energy than A, consequently, A is a *complete radiator* or a perfectly black body when within B, and it also follows that the interior of B radiates as a perfectly black body. A piece of polished platinum and a piece of carbon would appear equally bright within B, if viewed through a small hole, but if quickly removed the platinum would appear less bright than the carbon, for it gives out less light that is proper to itself since it is a good reflector but a poor absorbent and consequently a poor radiator, while C gives out more light that is proper to itself since it is a poor reflector but a good absorbent and a good radiator.

Now if the wall D were partly removed or were cooler than the rest of the walls it could not radiate to A as much as C does because it receives less from D. In this case we would have a slight departure from black body conditions. Hence the general statement:

The true temperature as indicated by a thermo-couple, of all substances heated in an inclosure, is the same as the black body temperature, as indicated by a pyrometer, which has been calibrated against a black body. If, however, the walls of the inclosure, wholly or in part, are cooler than the radiating object, its true temperature will in general be higher than the black body temperature. However, if the walls are reflecting, but at the same time cold, the difference in the two temperatures is less. This difference will be still less if the objects considered are of carbon or platinum black, etc.

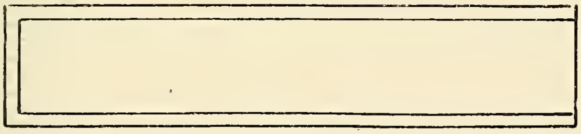

Fig. 3.

An experimental black body should therefore be as uniformly heated as possible and the aperture should be small, or if one end is entirely removed, as in Fig. 3, the length should be large compared with its cross-section.

It thus appears that in order to attain actual temperature by radiation methods the body whose temperature is desired must be made as nearly a black body as possible. In many cases this can be done with little difficulty. For example, if the temperature of an annealing oven is required, one could insert into the oven the closed end of a long metal or porcelain tube. The radiant energy coming from the bottom of this tube will be a close approximation to that of a perfectly black body. If black body conditions are not realized as an incandescent sheet of metal the temperature may be expressed merely as black body temperature, Kirchoff's absolute scale.

Laws of Black Body Radiation.—Stefan deduced from experiment, and Boltzmann deduced from thermodynamic considerations, the law that the total radiant energy emitted from a black body is proportional to the fourth power of the absolute temperature, or.

$$J = KT^4$$

where K is a constant.

The radiant energy emitted by a heated body is in the form of waves of diverse wave length. Most of the radiant energy is due to waves that are too long to affect the eye. As the temperature of the body is increased, the energy of all the emitted waves is increased, but the energy of the shorter waves increases more than that of the longer waves. That is, the distribution of energy among the waves of different lengths depends upon the temperature of the body.

Wien has also shown that the product of the absolute temperature T of some source and the wave length having maximum energy. λm in spectrum is a constant.

$$\lambda mT = \text{constant} \quad A$$

This is generally known as the displacement law or Wien's First Law. Wien also combines his first law with the Stefan-Boltzmann Law giving his second law.

$$J_{max}T^{-5} = \text{constant} \quad B$$

His most important investigation, however, was the investigation of spectral distribution of energy in the radiation of a black body in which he shows that for any particular wave length the relation between the energy emitted and the absolute temperature is as follows:

$$J = C_1 \lambda^{-5} e^{\frac{-C_2}{\lambda T}} \qquad (1)$$

where J is the energy corresponding to wave length λ and T is the absolute temperature. C_1 and C_2 are constants and e is the base of the natural system of logarithms.

The working principles of the following experiments are based upon these two laws, i. e., the total radiation and spectral radiation laws. In the first case black body temperature is determined by measuring the total energy, as in a Féry pyrometer which allows radiations of all wave lengths to fall upon a sensitive thermo-couple connected to a direct reading galvanometer. In the second case some particular wave length is used and the measurement of temperature is made photometrically by adjusting to equality two photometric fields produced by a standard source and the body to be measured. The intensity of radiation is varied by cutting down the objective aperture, as in Le Chatelier, or by a polarizing device, as in the Wanner, or by varying the intensity of the standard itself, as in the Holborn.

Since we are using mono-chromatic light a measure of the luminous intensity may be taken as a measure of the radiant energy. The intensity of radiation of a source may be defined as the ratio of the total energy emitted (including all wave lengths) to the energy falling upon unit surface. A part of the energy emitted by a heated body, however, may be luminous and both the luminous and total energy emitted by a body increases with temperature, but the total luminous energy is not proportional to the total energy emitted. The luminous energy of any particular wave length, however, is directly proportional to the total radiant energy emitted. Hence in any optical pyrometer when photometric comparison is made if mono-chromatic light is used the above radiation laws will hold.

Wanner Pyrometer.—It has been shown that the luminous intensities of two bodies may be taken as a measure of their temperatures, if monochromatic light is used, and since luminous intensities may be compared by the rotation of a Nicol prism we have a convenient means of measuring high temperatures.

In this method comparison is made between a standard lamp and the body whose temperature is sought. The standard used is a 6-volt incandescent lamp which is in turn compared with some primary standard as an amyl acetate lamp. For this work the primary standard is used merely as a check for the more convenient electric lamp and so long as it is reproducible so that the comparison lamp can always be brought to the same condition, we are not concerned with its intrinsic intensity or temperature. Photometric comparison is made of the comparison lamp and the unknown source by adjusting to equal brightness two halves of a photometric field by means of a polarizing arrangement, monochromatic red light being produced by a direct vision prism.

The intensity of the unknown source in terms of the comparison lamp, taken as unity, is

$$J = \tan^2\phi$$

where ϕ is the rotation of the Nicol prism.

Le Chatelier Pyrometer.—Le Chatelier's optical pyrometer compares the luminous intensity of the red radiation from the body whose temperature is derived with the red radiation from a standard light source. The radiation from the body whose temperature is to be measured, traverses the diaphragm S, Fig. 4, and the objective O. A part of the radiation grazes the right edge of the mirror M and is brought to a focus at the focal plane of the eye-piece A. Light from the central portion of the flame of the comparison flame L traverses the objective O′, is reflected from the inclined mirror M and is also brought to a focus in the focal plane of the eye-piece. Thus two images, one of the source whose temperature is sought, and one of the comparison flame, are found side by side, in the focal plane of the eye-piece. These two images are simultaneously observed by means of the eye-piece A provided with a piece of red glass for rendering

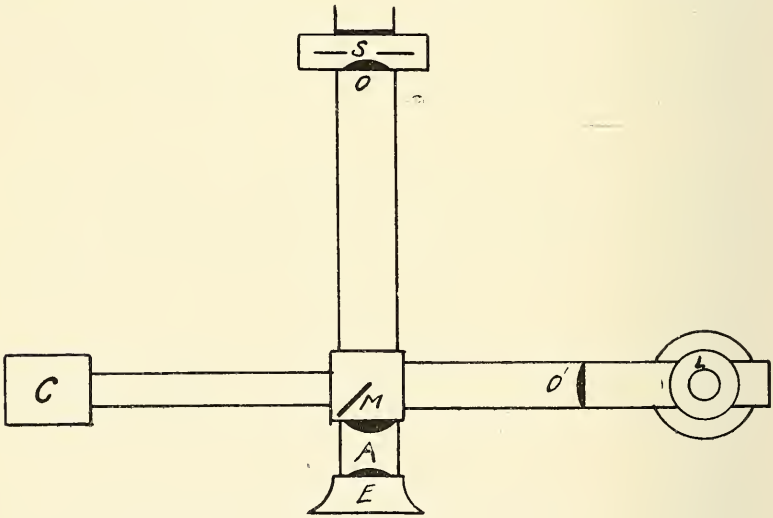

FIG. 4.

the radiations that enter the eye of the same wave lengths. By adjusting the size of the aperture in the diaphragm S. these two images can be brought to the same luminous intensity. The distance from the objective O to the focal plane of the eye-piece can be varied in order to focalize the radiation from the luminous source, and the distance can be read directly from a scale engraved on the draw tube. The aperture in the diaphragm S is square and the length of one side can be read directly from the screw head which operates it.

The intensity of the unknown source in terms of the intensity of the comparison lamp taken as unity, becomes

$$J = \left(\frac{1}{d}\right)^2$$

where d denotes the length of one side of the square aperture S. Due to the lack of monochromatism of the red glass this instrument is not so accurate as the Wanner.

Holborn-Kurlbaum Pyrometer.—In this method the luminous intensity of the comparison source is varied until a photometric balance is obtained between its image and the image of the incandescent object in question. In the H.-K. (Holborn-Kurlbaum) pyrometer shown in Fig. 5 a small electric lamp L is placed in the focal plane of the objective O and the same

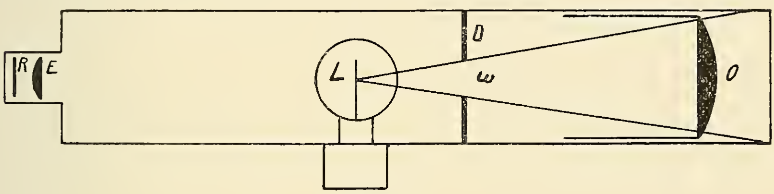

FIG. 5.

is viewed by means of an eye-lens E. In making an observation the pyrometer is focused upon the object whose temperature is sought, thus bringing the image of the object in the plane of L. The current through the lamp is adjusted by means of a rheostat until the lamp filament disappears against the bright background. The value of the current strength can be read direct from a milli-ammeter.

In order to measure temperature with this instrument it must be empirically calibrated by means of a black body. A curve may then be plotted with current in milli-amperes, I, and temperature, t, in degrees C. To determine an unknown temperature, it is only necessary to focus the instrument upon the object in question and adjust the current through the lamp until the filament disappears against the bright object. The pyrometer then indicates the black body temperature unless black body conditions are realized, in which case it indicates true temperature, i. e., thermodynamic temperature.

The reading of the ammeter will be independent of the distance of pyrometer from object so long as the solid angle w, Fig. 5, is constant. This is accomplished by means of the diaphragm D. When the instrument is focused for distant objects, i. e., when O is drawn near L, the solid angle w would be increased if it were not for the diaphragm D.

The light which reaches the eye is rendered approximately monochromatic by a red glass R placed before the eye-piece but for temperatures below 800° C. this is not necessary and above 1,200° C. two glasses are generally used. For the extrapolation of the experimentally determined curve for high temperatures Wien's third law may be used. For these high temperatures beyond the safe limit of the lamp three different methods are used for cutting down the incident radiation a determinate amount; absorbing glasses, mirrors, and sector discs.

Since the absorbing power of the absorption glasses is different for different wave lengths, if there is any lack of monochromatism in the red transmission glasses, which is generally the case, Wien's law will not hold for high temperatures.

To overcome this difficulty Henning[6] has combined an H.-K. pyrometer with a Hilger constant deviation spectrometer so that homogeneous light may be used. This instrument has the further advantage that any part of the spectrum may also be employed. Dr. Mendenhall has recently devised a spectroscopic eye piece to accomplish the same purpose.

The H.-K. pyrometer is probably the most sensitive pyrometer now in use.

Féry Total Radiation Pyrometer.—From a consideration of the Stefan-Boltzmann radiation law we have seen that the energy radiated by a black body is proportional to the fourth power of the absolute temperature, or,

$$J = KT^4 \qquad (2)$$

From this relation it is evident that a comparatively rough method of determining the energy radiated would yield fairly accurate results of temperature measurements.

The Féry radiation pyrometer is shown in detail in Fig. 6. Radiation from an incandescent body is focused upon a minute and sensitive thermocouple C, by means of a lens A'. In order to calibrate the pyrometer directly in terms of the Stenfan-Boltzman law the lens should be transparent for all radiations and this is best effected by using a fluorite lens which for temperatures above 900° C. does not absorb an appreciable portion of the incident radiation. F is a rack and pinion for focusing the radiation upon the thermo-junction. The screens C and D protect the junction from

[6] Zeitschrift Für Instrumentenkunde, März, 1910.

extraneous rays. The diaphragm E provides a constant angle aperture, which is a necessary condition for the instrument to be independent of focusing. The thermo-junction leads are connected to the posts b and b_1, which are in turn connected to a galvanometer. In making a temperature measurement the image of the incandescent object is focused upon the

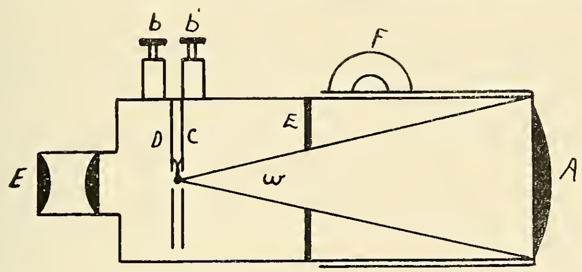

FIG. 6.

thermo-couple by means of the eye piece E, and care must be taken that the image is larger than the thermo-couple. It is evident from Equa. 2 that if the galvanometer has a uniform scale and the temperature T_1 is known corresponding to a scale reading R_1, the temperature T_2 for any other reading R_2 may be found from the relation.

$$T_2 = T_1 \sqrt[4]{\frac{R_2}{R_1}}$$

When the limit of the scale is reached the calibration may be extended by means of a diaphragm placed before the objective or by shunting the galvanometer. In technical practice, however, a glass lens is used and the instrument is calibrated empirically against a black body whose temperature can be determined. This instrument is also made with a gold reflector instead of a lens. Féry[7] has recently brought out a new pyrometer which is similar to the above with the exception that the temperature of the incident radiation is measured by means of a minute expansion spiral consisting of two metals with dissimilar expansion coefficients. This mechanical device renders the instrument more robust but does not admit of so great accuracy as the thermoelement.

Morse Thermo-Gage. This is somewhat similar to the Holborn-Kurlbaum pyrometer in that it utilizes the disappearing filament principle but it is not nearly so precise since it is not provided with any lens system

[7] Engineering, May 14, 1909.

or monochromatic glasses. It is simply an incandescent electric lamp in a black tube and it is operated and calibrated in a similar manner to the Holborn instrument.

While there are a number of instruments, more or less reliable, which may be bought from scientific shops, the above list represents the ones in most common use. In the opinion of the author it is neither necessary nor advisable to equip a high temperature laboratory with an elaborate outlay of expensive commercial apparatus. The object of such a laboratory should be to teach the student the fundamental principles of the subject, the application and limitations of these principles to commercial instruments and to train the student in the use of a few types of instruments. After having mastered the principles of radiation pyrometry the student will have no difficulty in making a temperature observation by means of a direct reading Féry spiral pyrometer or any other similar instrument.

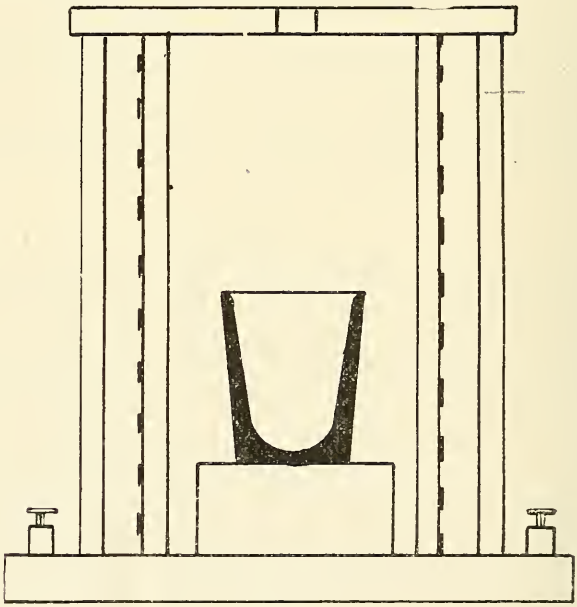

FIG. 7.

For the purposes of calibration or standardization of instruments the laborator should also include a boiling point apparatus for each of the fixed points, or if the fusion temperatures of the metals are used, a melting furnace.

To calibrate a platinum couple, the most convenient fixed points are the fusion temperature of copper, antimony and zinc. These metals may be melted in small graphite crucibles. The size of crucible chosen and the quantity of metal used should be such that at least 5 cm. of the couple may be immersed in the metal. The crucible may be heated in any suitable manner, but an electric resistance furnace is perhaps the most convenient. Fig. 7.

One form of furnace consists of two concentric cylinders of fire clay, or porcelain, placed upon a base of the same material. A suitable cover also is provided with a hole for admitting the couple. The inner cylinder is overwound with fine nickel wire or ribbon and the crucible, to be heated, is placed within this cylinder. It should be placed at about the center so as to be uniformly heated.

Another form of furnace which is less likely to get out of order, but which on the other hand is not so satisfactory for precise work, is shown in Fig. 8. This consists of a rectangular trough of brick work (a, Fig. 8).

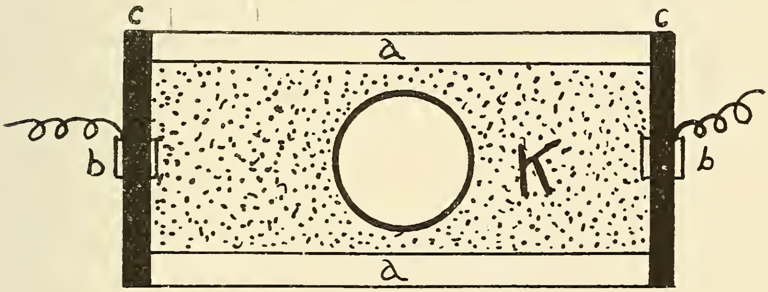

Fig. 8.

The inside width should be somewhat greater than the diameter of the crucible to be used and the depth slightly greater than the height of the crucible. The ends of the trough are closed with carbon plates cc, which carry binding posts bb, for the connecting wires. The intervening space K is filled with a granular resisting material, commercially known as "Kryptal." The connectors at bb are connected to some source of e.m.f. either DC or AC. The amount of current may be regulated by varying the density of the mass of kryptal used. Thus, when a large amount is used and when it is packed down well a large current will pass through the furnace. The top of the entire furnace should be covered over with bricks.

In order to calibrate or standardize a pyrometer it is necessary to have a luminous source whose black body temperature is accurately known. The primary standard must be some form of a heated inclosure whose walls can be maintained at a uniform constant temperature. Some means must also be used for determining the true temperature of the inside of the inclosure.

This is generally accomplished by some form of an electric resistance furnace, as shown in Fig. 9. It consists of a central porcelain tube overwound with thin platinum foil through which passes an electric current which can be adjusted to maintain any desired temperature up to about 1,600° C. Concentric with this tube are two shorter ones which, with the intervening air spaces, minimize the radiation. Some form of thermo-couple is placed in one end so that the hot junction is near the

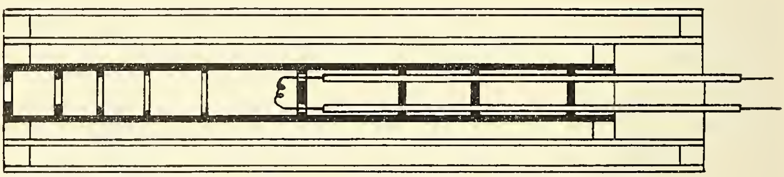

Fig. 9.

center of the tube. If there is a cold junction it should be placed in crushed ice. The thermo-couple may be either connected to a potentiometer or a sensitive potential galvanometer which reads millivolts, and by means of a previously determined calibration any temperature may be determined. Except in refined work the ice point is not necessary. The furnace is connected in series with a rheostat and 110 v. DC.

For the calibration of the Wanner or Le Chatelier pyrometer it is not necessary, as will be shown on the following pages, to know but one black-body temperature so that as a working standard any convenient luminous object such as a frosted globe incandescent lamp, which would give a uniformly illuminated area of about 1 sq. cm., might be used if its black-body temperature at some particular current strength were accurately known.[8]

For pyrometers like the Holborn-Kurlbaum (H.-K.), however, which can only be calibrated empirically, it is necessary to have a black body

[8] Physical Review, Vol. 31, No. 4. Oct., 1910.

whose temperature can be varied. This is generally done by means of an electric furnace, but when a Wanner, Le Chatelier, or a calibrated H.-K. is at hand it is easiest accomplished by direct comparison.

The comparison source may be a thin platinum strip, heated electrically or a wide filament incandescent lamp. The H.-K. may be sighted on one side of the strip and the calibrated pyrometer on the opposite side. The black body temperature of the strip can be determined by means of the calibrated instrument and at the same time the reading of the H.-K. comparison lamp can be taken.

In the case of a wide filament carbon incandescent lamp it has been shown that if it is properly aged for about 20 hours at 1,760° C. it will remain sufficiently permanent for a secondary standard for 15 or 20 hours.

If a lamp is calibrated in terms of black body temperature and current strength by means of a pyrometer it may be used as a standard of comparison for calibrating pyrometers just as a black body would be used.

CALIBRATION.

In the foregoing a number of instruments have been described for the estimation of high temperature, each class utilizing some effect of temperature such as the change of resistance, development of small electromotive force, change of luminous intensity, etc., and it now remains to indicate how each of these instruments may be calibrated to read in terms of temperature, °C.

Electric-resistance Pyrometer. A resistance pyrometer may be calibrated by comparison with a calibrated instrument or by a number of known temperatures such as the boiling points of liquids or fusion points of metals, and in general three points are quite sufficient to completely calibrate the pyrometer, but no simple equation can be given for all metals. For platinum, however, the case is somewhat different, as an extensive study has been made of platinum resistance thermometry.

Callender[9] defined platinum temperature Pt as follows:

$$pt = 100 \frac{R - R_0}{R_{100} - R_0}$$

where R = the observed resistance at the temperature t.
where R = the observed resistance at 0° C.
where R = the observed resistance at 100° C.

[9] Proc. Roy. Soc. 41, p. 231, 1886.

The relation between platinum temperature and centigrade temperature from — 100 to 1.100° C. is given by the equation

$$t - pt = \delta \left(\frac{1}{100} - 1 \right) \frac{1}{100}$$

where δ is a constant depending upon the purity of the platinum. For pure platinum δ is 1.50 and for impure it is somewhat higher. Such a pyrometer is usually calibrated by measuring its resistance at the melting point of ice (0° C.), boiling point of water (100° C.), and some other temperature, such as the boiling point of sulphur (444.7° C).

Temperatures measured on such a pyrometer will agree with the temperatures measured on the gas scale in the range 0 to 1,100° C. to within the degree of reproducibility of the latter.[10]

Thermoelectric Pyrometer.—It has been shown by a number of experimenters that in order to completely calibrate a thermo-couple, point by point comparison is unnecessary, but that three or four known temperatures or fixed points are sufficient. No general equation can be given that will accurately fit all thermo elements, but for most metals, at least within a limited region, the relation between the potential difference in millivolts and the temperature in degrees centigrade is sufficiently well represented by the general quadratic equation

$$e = a + bt + ct^2 \qquad (3)$$

where a, b and c are constants that can be determined if three temperatures are used. It can easily be determined by experiment how well this formula will hold for any given couple. Three points should be chosen which will cover the region for which the couple is to be used, and a curve drawn through these points. If the curve is nearly a straight line it can be represented by Equa. 3.

The fixed points are generally the ebullition of water, analine, naphthaline, sulphur, etc., or the freezing of such metals as tin, zinc, antimony, copper, silver, gold, etc. The former, with the exception of sulphur, are obtained with less difficulty than the latter, but are of value only for low temperatures.

For a copper-constantan couple the most convenient fixed points are the fusion temperature of antimony (630.7° C.), zinc (419.4° C.), and tin (231.9° C.), and for a platinum couple zinc, antimony and copper (1,083° C.).

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[10] Bulletin Bureau of Standards, Vol. 6, p. 196.

Radiation Pyrometers.—Equa. (1) may be written in the form

$$\log_{10} J = K_1 - K_2 \frac{1}{T}, \qquad (4)$$

where

$$K_2 = C_2 \frac{\log e}{\lambda}.$$

C_2 for a black body temperature equals 14,500 when λ is given in terms of μ.

Equa. (4) may be applied to any pyrometer, using monochromatic light, in which the luminous intensity can be varied in a continuous and determinate manner as in the Wanner and Le Chatelier. Either of the instruments will, therefore, indicate temperature indefinitely high, but the limit of accuracy is reached at about 2,000° C., so that at higher temperatures the incident radiation is usually cut down by means of one or more absorption glasses. The amount by which it is cut down is determined as follows:

Let J′ equal the luminous intensity of the incident radiation and J_1 the value as indicated by the instrument when one glass is used, then

$$J' = JR,$$

where R is the absorption factor. For two absorption glasses

$$J' = (JR)\ R = JR^2,$$

and for n glasses

$$J' = JR^n \qquad (5)$$

also

$$R = J'/J. \qquad (6)$$

The general expression, then, for the relation between energy and absolute temperature, is from (4)

$$\log J' = K_1 - K_2 \frac{1}{T}.$$

From (5)

$$\log J + n \log R = K_1 - K_2 \frac{1}{T},$$

whence

$$t = \frac{K_2}{K_1 - \log J - n \log R} - 273, \qquad (7)$$

where t is temperature in degrees C.

Equa. (7) is a general equation for connecting the relation between temperature t and luminous intensity J and can be applied to any pyrometer in which J can be determined theoretically. For the Wanner pyrometer $J = \tan^2 \phi$, where ϕ is the angle of rotation of the nicol analyzer, and for the Le Chatelier $J = (1/d)^2$ where d is the length of one side of the iris diaphragm. K_1, K_2 and R are constants and can all be determined without reference to any temperature observation.

Wanner Pyrometer.—This method of calibration will be made clear by an example. For a particular Wanner pyrometer the value of λ was 0.656 μ.

Therefore

$$K_2 = \frac{14.500 \times 0.4343}{.656}$$
$$= 9,600.$$

It is seen from (4) that if K_1 were known, various values of ϕ might be substituted in the equation and the corresponding temperatures calculated. Now by assuming some angle of rotation ϕ for some particular temperature T, as in the above case, K_1 may be found. For example, let

$$T = 1273 \text{ and } \phi = 45°.$$

Then from (4)

$$K_1 = \log \tan^2 \phi + K_2 \frac{1}{T}$$
$$= 0 + \frac{9,600}{1,273} = 7.55.$$

For $\varphi = 10$, and $n = 0$, t may be calculated from (7),

$$t = \frac{9,600}{7.55 + 1.51} - 273$$
$$= 787° \text{ C.}$$

Le Chatelier Pyrometer.—The wave length for the red glass used on a Le Chatelier pyrometer was found to be 0.649 μ . The constant K then becomes

$$K_2 = \frac{14,500 \times 0.4343}{0.649}$$
$$= 9,700.$$

Holborn-Kurlbaum Pyrometer.—Such an instrument must be calibrated empirically and the calibration will be different for every lamp used. It has been shown[11], however, that the relation between temperature and current through the lamp may be represented by the general quadratic equation

$$I = a + bt + ct^2,$$

so that three known temperatures are sufficient to completely calibrate the instrument. Such a pyrometer may be readily calibrated, without the use of a black body, by means of a standard pyrometer comparison lamp as explained above. If such a lamp is not properly calibrated in terms of temperature and current its black body temperature, for any value of current, may be determined by means of another calibrated pyrometer. A platinum ribbon may be used in the same way.

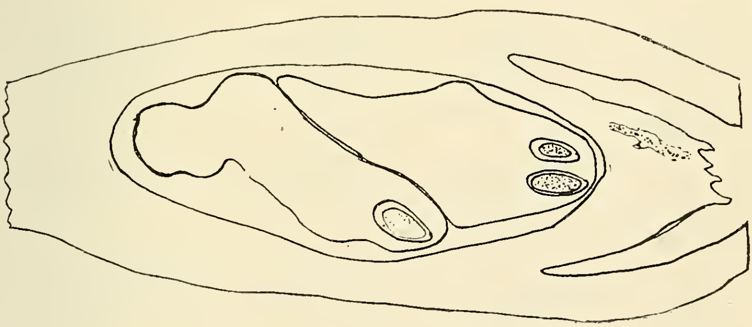
Physics Laboratory,
Purdue University.

[11] Bulletin, Bureau of Standards, Vol. I, p. 255.

Two Pine Gametophytes in One Ovule.

By M. S. Markle.

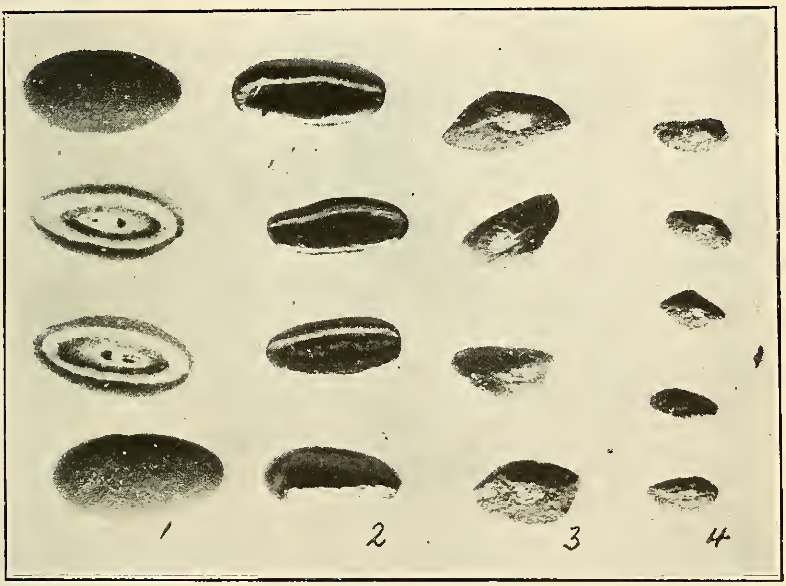
In sectioning some pine material of unknown origin, I recently found one ovule that had in it two well-developed gametophytes, each of which had developed archegonia. This probably means that two megaspores functioned instead of the usual one. I understand that the abnormality has also been noticed by Miss Sargent. The two gametophytes occupied the positions shown by the accompanying sketch.



Indiana Weeds—Their Control and Eradication.

By G. M. Frier, B. S. A., Assistant Agricultural Extension, Purdue University.

The subject of weeds is one in which the people of Indiana are taking more and more interest each year. The farmers, who constitute a large percentage of the population of the State, are much concerned about the weed situation now confronting them. There are growing on the farms



1. Bracted Plantain.
2. Buckhorn.
3. Black-seeded Plantain.
4. Common or Dooryard Plantain.

of Indiana today, scores of species of weed pests, and in many cases enormous numbers of each species. This results in smaller crops and smaller profits. Weeds are robbers in a very distinct and definite sense. To the citizens of our town and cities they are unsightly and offensive, disfiguring as they do lawns, gardens, streets and vacant lots. There are being received at the Agricultural Experiment Station, in ever increasing numbers, inquiries concerning weeds of the farm, lawn and vacant lot, their time of flowering, time of seeding, distribution, method or methods of propagation, prolificacy, means of control, or eradication, and similar queries, showing

Dog Fennel or Mayweed.

that there is a general desire and demand on the part of our people for information along this line. The following paragraphs will therefore attempt to take up in a brief and condensed way some of the important phases of the weed problem as we have it in Indiana today.

HOW WEEDS SPREAD.

Nature has provided in an interesting and wonderful way for the reproduction and dissemination of plants. A large number of common weeds, such as the dandelion, sow thistle, wild lettuce, groundsels, white-top, ironweed, boneset, joe-pye weed, true thistles, produce seeds to which are attached light, fluffy, parachute-like structures which very materially facilitate their dispersal by the wind. Other weeds, such as yarrow, ox-eye

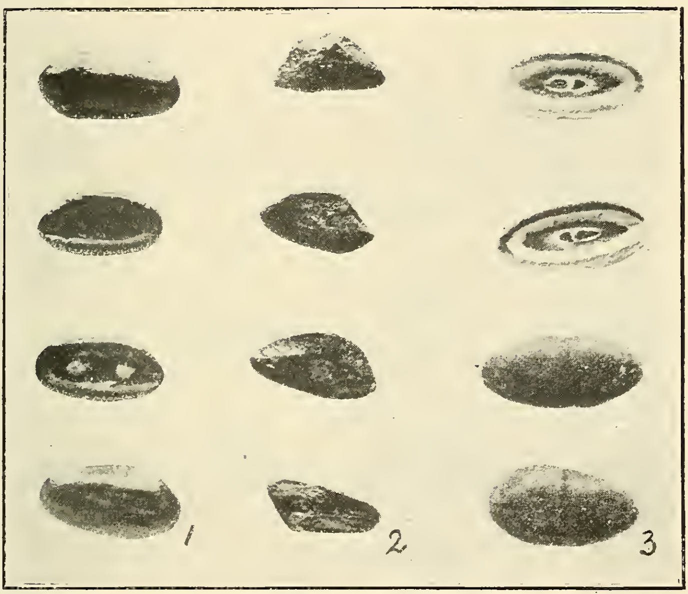
Curled or Sour Dock.

daisy and curled dock, are either very light, or have light membranous attachments. There is a group of weeds, including old witch grass, Russian thistle, tumbling pigweed and others, which have the characteristic of breaking off when mature at or near the surface of the ground, and, rolling hither and thither, far and wide, over the fields, discharge thousands of weed seeds as they go, in this way inoculating our fertile soils with crop-reducing weed pests.

Another agency making for the spread of weeds, is water. The seeds or fruits of many plants, especially those growing in or near water, are fitted for dissemination by this agency. Such fruits are those of narrow-leaved dock, showing a round, rough, spongy growth on the outside of each of the close fitting, persistent sepals; of the Asa-Gray sedge, with its inflated sack attached to the fruit; of the arrowhead, with its corky margined fruits which are able to float on the water.

Black-seeded Plantain

The seeds or fruits of many weeds are in one way or another carried by animals. Thus when slightly moist, the seeds of peppergrass, plaintain, groundsel, dropseed grass, and many others, are sticky and will adhere to animals' feet or covering. Some sedges, chickweeds and catchflys have sticky glands, by means of which they cling to passing objects. The fruits of the avens, and the burs of the common burdock, are armed with hooks, and the fruits of the bidens or beggar's ticks with spines, by means of which they cling to and are carried about attached to the covering of animals or the clothing of human beings. Similarly provided for are hounds-tongue, stick-tights, tick trefoil, bed-straw, cocklebur, sandbur, motherwort and many others. Further, birds and animals devour very large numbers of many kinds of weed seeds, not all of which are acted on by digestive juices to such an extent as to destroy their viability. These are scattered in bird and animal excrement, and grow into new and vigorous plants.



1. Buckhorn.
2. Black-seeded Plantain.
3. Bracted Plantain.

Noxious weeds are spread through the use on farms of manure and sweepings from stock and other cars, and by means of packing about merchandise and nursery stock. The moving of threshing and other machinery from place to place without first cleaning them out thoroughly, the use on farms of manure from livery stables in towns and cities, all help to spread noxious weeds. The use of impure and adulterated crop seed on our farms is responsible in a large measure for the spread of weeds. Much of the clover, alfalfa and grass seed used in Indiana today have mixed with them considerable quantities of weed seed and other impurities, which, scattered on the land, means weedy fields and reduced crops. Many lawns are excessiveiy weedy because of impure seed scattered on them.

THE INJURY WEEDS DO.

Indiana farmers are losing many hundreds of thousands of dollars each year because of the weed situation existing in this State. A continuous and strenuous effort to control weeds ought to be made, because—

1. Vervain.
2. Mayweed or Dog Fennel.
3. Catmint.
4. Night Flowering Catchfly.

1. They rob crops of plant food and moisture. Plants feed as really as do horses or cattle. As growing crops remove plant food from the soil, the farmer must count on the necessity of returning an amount of plant food to the soil at least equal to that removed, if he expects to continue to grow crops abundantly and profitably. Weeds require approximately the same kinds of plant food as do farm crops, and they require them in approximately the same amounts. Crops suffer when weeds use up a large share of plant food. To put this plant food into the soil the farmer expended money, time and labor. Further, an adequate supply of moisture in the soil is indispensable for the successful growing of crops. Weeds, like

other plants, are constantly, during the growing season, pumping water from the earth. Much of this ultimately goes off into the air, and, as far as crops are concerned, is wasted. For the formation of every pound of dry matter in a corn crop, there are required 360 pounds of water. Oftentimes crops suffer seriously for moisture owing to the presence of weeds, and as a result these crops are much reduced in quantity and value.

2. Weeds choke out the desired crops. No field can produce excellent crops of corn or wheat and a heavy growth of weeds at the same time. This, in agriculture, is as impossible as in physics it is impossible for two bodies to occupy the same space at the same time. When a heavy growth of weeds is present, corn, vegetables or any other crop, are likely to be weak and spindling.

3. Weeds furnish a refuge and shelter for the protection and propagation of insect and fungus enemies of crops. Fruit, vegetables and field crops have very many more such enemies than is ordinarily realized. The keeping down of weeds and the removal or plowing under of refuse material, will in no small measure reduce insect and fungus enemies of crops.

4. The presence of weeds in considerable quantity makes every operation on the farm—plowing, harrowing, seeding, cultivating, harvesting, marketing, etc., more expensive. Further, on a farm where weeds are not intelligently and continuously combated, machinery is more short-lived, and repairs are needed oftener.

5. Property overrun with weeds is less attractive, and will not sell as high as property giving indication of thrift, intelligence, and successful management. Moreover, weeds are an offense to one's æsthetic taste, and an eyesore to all passers-by.

In view of these facts, it is very plain that weeds are distinctly robbers, and should be controlled and, where possible, eradicated. To deal effectively with weeds, it is necessary to know something of their characteristics, their life history—are they annual or biennial or perennial? How do they propagate? When do they flower? When do they seed? Do they produce large quantities of seed? Does this seed retain its vitality in the soil for a long time or but a short time? To facilitate the gaining of information on weeds from reading, lectures or conversation it is a decided advantage to know common weeds at least by their commonly accepted names. In these later days it is not difficult to obtain a working knowledge of our Indiana weeds. Books and bulletins covering the subject are available.

The Agricultural Experiment Station or the U. S. Department of Agriculture will gladly furnish bulletins on weeds or weed seeds, or name specimens of weeds or seeds sent in.

It is not possible in this brief article to take up a consideration of a

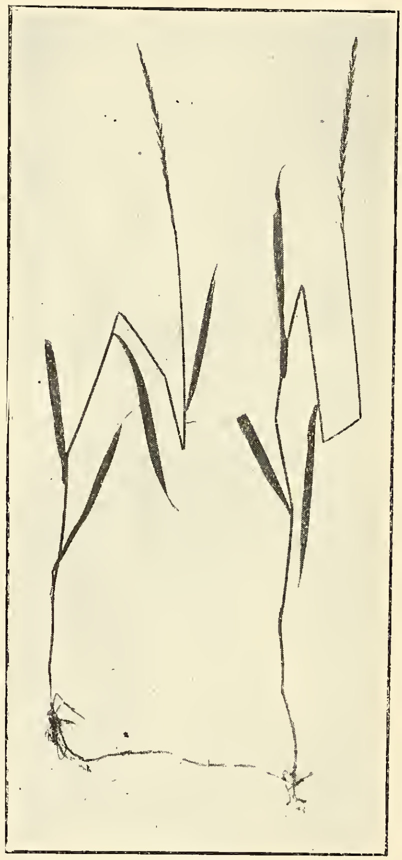
Dodder on Clover.

large number of individual weeds. It must of necessity suffice to consider the larger groups into which all our weeds fall—annuals, biennials and perennials. Annuals are those which grow from seed, and in turn produce flowers and seed, all within the one growing season. They are, as a rule, fibrous rooted and propagate by seed only. Many of them produce seed in great abundance. The seeds of some annuals when buried in the soil retain their vitality for long periods. Mustard seed, for instance, has been known to lie in the soil for a quarter of a century and then when placed in a favorable environment, grow into vigorous plants. In this class we have such common weeds as dodder, foxtail, smartweed, Russian thistle, crabgrass, pigweed, lamb's quarters, dog fennel, barnyard grass, tickle grass, bracted plantain, ragweed, corn cockle, night-flowering catchfly, mustard and whitetop.

Buckhorn.

Biennials are those plants which spring from seed and produce only a cluster of leaves the first season. In these leaves are manufactured and stored large amounts of plant food for use during the second season of growth. During the second season, a flower stalk is sent up and many seeds formed, after which the plant dies. This group depends on seed for propagation. Here belong wild carrot, wild sweet clover, burdock and common evening primrose.

Perennials are those which live on indefinitely year after year, reproducing from seed, or, in addition, from buds near the crown of the plant, as in buckhorn, or from buds here and there along running underground parts as in Canada thistle. Many perennials are persistent and particularly



Twitch or Couch Grass.

noxious. Here belong horse nettle or sand brier, twitch or couch grass, sour dock, sheep sorrel, field bindweed or wild morning glory, ox-eye daisy, yarrow, wild barley, black-seeded plantain and others. Farmers and other property owners are urged to acquaint themselves with the common weeds, their names and characteristics, for on these latter in a large measure are based methods of control or eradication. The following suggestions in regard to weed control apply to all classes of weeds:

1. Buy seed which is the purest obtainable and of strong vitality.

2. Before buying, test a sample of it, or send a sample to the Branch Seed Laboratory, Experiment Station, Lafayette, to be tested for purity and germination. In this way only can any one learn the character of seed he proposes using, in regard to freedom from weed seed and in regard to viabliity.

3. As far as possible, prevent weeds about the farm from seeding. Pulling, the use of the scythe along ditches, roads, lanes and fences and about the yards and buildings and in the wood lot, as well as the use of the mowing machine where possible, will accomplish this in a large measure.

4. Thoroughly and repeatedly cultivate corn crops so as to keep weeds down.

5. Breaking weed-infested ground in the fall and harrowing at short intervals and repeating the harrowing in spring to encourage weed seed lying in the soil to germinate and to destroy the seedlings, is to be recommended.

For biennials repeated cuttings during the second season of growth, pulling or spudding where only a few plants are in evidence, together with the introduction of a hoed crop (corn or potatoes, say), are effective.

Perennials will need more extensive treatment than is indicated above. A treatment such as the following is suggested:

Plow in the fall and follow with frequent harrowings both in the fall and in the spring. About the end of May sow with rape in drills, or broadcast millet, cowpeas or Canada field peas and oats. When well advanced. use these crops for pasture. or feed in the yard to supplement other pasture crops. Animals. especially hogs and sheep, are very useful in destroying weeds on the farm. Plan to use them as extensively as possible. Follow the smoother crop (rape, millet, etc.) with wheat seeded heavily with clover. When wheat is off let a crop of clover grow up. Pasture this or plow it under. Follow this with a well-cared-for corn crop. This method is in addition to general suggestions given previously. Eternal vigilance. care and persistence is the price of a clean farm. That a clean farm, indicating thrift, intelligence and taste, is more attractive, satisfying and profitable than a weedy, carelessly operated one, there can be no question.

In cities and towns the least that can be done is to frequently cut weeds with the scythe or other tools, so that they can not form seed. Street commissioners and other citizens possessed of a goodly amount of energy and civic pride can do much to create and maintain a "city beautiful" so far as neatness of streets, lanes, vacant lots, etc., are concerned. In connection with lawns, mention might here be made that it has recently been learned by experiment stations, that the use of iron sulphate on lawns and weedy areas is profitable, practicable, effective and cheap, if rightly applied. By it dandelions, plantain and other weeds can be controlled. It is coming into extensive use on farms in some parts of the United States. Suitable machinery is made for the application of iron sulphate either on a large or a small scale. The treatment of the subject of the use of iron sulphate can not be taken up in detail here, but the writer will be glad to furnish any information desired on the subject at any time.

The Preglacial Valleys of the Upper Mississippi and its Eastern Tributaries.

Harry M. Clem.

So far as the writer is aware, there has been no attempt to compile a map showing the results of researches upon the preglacial drainage of the region indicated in the title. The following paper addresses itself to that task, together with a brief discussion of the reason for believing that certain streams shown on the map were preglacial. Only the briefest outline can be given in this short discussion, which merely undertakes to pioneer the large field lying before it.

The attempt has been made to map accurately the preglacial channels of the area in question, but this may not always have been attained, for several reasons. The literature is not adequate in all the fields of the area, and often the statements made are not so clear as might be desired. The word "probable" is very frequently used and renders mapping difficult, if not impossible. Occasionally, authors differ, and in such cases the one which seemed to be the better authority is followed, and the dissenting theory mentioned in the text. No attempt has been made to give a critical discussion of the different theories. Any reader who may desire more detailed information than this paper furnishes can find all that is of importance in the accompanying bibliography,[1] or he may look there for correction or verification of any points in the discussion with which he may disagree.

The greater portion of the region covered in this paper is so deeply buried in drift that only the major details of the ancient preglacial topography are apparent. The multiplicity of minor topographic details that give final expression to the landscape are so completely buried from sight that it may never be known how the ancient surface appeared before the advent of the glacier. Only by a multiplicity of borings could a general idea of the details of that buried topography be obtained, and that is impossible except where some deep-seated natural resource induces men to sink deep wells. Thus innumerable small valleys have been obliterated and

[1] Not published here.

lost to history. The larger valleys generally remain sufficiently unobscured to enable geologists to trace their courses, either continuously or at intervals close enough together to enable a safe inference to be made concerning their previous courses. The larger the valley the better chance it had in general to leave behind itself traces of its former course, for, occupying the lowest part of the surface and carrying great quantities of water, it was automatically kept open by drainage from the melting ice. Yet even the largest river trenches were in imminent danger of defacement. Such an instance is found in Jay and Adams counties, Indiana, where there are signs of a huge valley whose bottom is buried beneath nearly 400 feet of drift and no traces left of its existence on the surface. Another case is that of the preglacial Mississippi where it turns southeastward to the Illinois valley just below Clinton, Iowa.

The map shows large hiatuses wherein there are no preglacial streams indicated, but they certainly exist buried in several hundred feet of drift. West and south of the basin of Lake Michigan and between that basin and the Lake Erie depression in northern Indiana and Michigan no details are shown, and only a few larger courses suggest probabilities of preglacial existence. The depth of the drift and the absence of deep-seated natural resources do not encourage the digging of a sufficiently large number of deep wells to permit the construction of a topographic map of the preglacial surface. Enough, however, is known to assure us that the ancient drainage lines were quite different in many details from the present systems.

Without further preliminaries we shall discuss the pros and cons regarding the claims of the streams shown on the maps to a preglacial ancestry. For the sake of convenience of treatment, the area is divided according to the several smaller drainage basins which make up the greater Mississippi basin. This will be found convenient because there are wide elements of correspondence between the present and the preglacial drainage basins, as a glance at the generalized map will show. The basin of the Great Lakes, which seems to cut out a portion of the Mississippi basin, and which is separated by a very low primary divide, over which the lakes drained in the Ice Age, is discussed briefly.

THE PREGLACIAL DRAINAGE OF THE UPPER MISSISSIPPI BASIN.

The preglacial divide of the northern side of the Upper Mississippi basin is not definitely determined. It can be pretty definitely located at

Huron, N. D., where there is a col and a constriction in the James river, a preglacial divide, over which the reversed headwaters of that stream now run southward. From Huron eastward its location is a matter of speculation backed up with slender evidence. From here it may have turned south across the present Mississippi valley somewhere near "military ridge," as Hershey (46) would have it, and then eastward, or it may have turned north some distance east of Huron along the east edge of the basin of the Red river, but this will be discussed more fully later. "Between the Rock river drainage line and Lake Michigan there is a somewhat less elevated belt of limestone, which extends curvingly in a direction east of south into western Indiana." (Leverett, 64:16.) Somewhere in eastern Illinois or western Indiana a spur ran south, probably near the present divide between the Wabash and Illinois system separating the preglacial as well as the present basins. The location of the divide north through Wisconsin is not well known, but there is no doubt that it was east of the present "driftless area."

Even if it were possible and profitable, space does not admit of a detailed discussion of secondary divides, which can generally be inferred from the location of the preglacial valleys. After calling attention to the fact that the present Mississippi river has evidently a system of drainage widely different from the system or systems which were operative in preglacial times within the region now drained by it, Leverett says: "Besides opening a new channel at each of the rapids, the stream apparently is occupying sections of two or more independent preglacial valleys." (64:461.)

As to the course of the Mississippi above St. Paul, Chamberlain suggested, in 1879, that it is post-glacial (19:253), but that it probably follows the preglacial channel in short stretches. Hershey, in 1897, agrees with the suggestion.

Hershey has the following to say concerning the preglacial valley above St. Paul: "The high upland area which trends north and south on its eastern side at some distance from its immediate border, continues without a change for many miles to the north, passing to the east of Lake Phalen. Although deeply covered with drift, it is undoubtedly based on an upland area of rock. To the west of it, and in the direct line of continuation of the old Mississippi valley, there is a topographical depression which trends for many miles to the northwest. It is occupied in places by lakes, the most important of which is lake Phalen. This, in my opinion, will probably be found to be the ancient course of the Mississippi river. That it is the position of a preglacial valley is indicated by a deep well at the St. Paul Harvester Works, situated in the present topographical depression, which penetrated rock at 235 feet beneath the surface or 628 feet above the sea, which is 55 feet beneath the present low-water level of the Mississippi river at St. Paul. The lake Phalen depression is separated from the head of the Mississippi cañon valley by a moraine which is evidently based on a comparatively low surface, for it does not rise nearly as high as the drift to the east or west. As seen from the opposite side of the valley, its escarpment or bluff at the head of the old cañon valley shows such topography as is usually produced by the erosion of drift. In short, all the evidence favors this lake Phalen depression as the position of the pre-glacial continuation of the Mississippi cañon valley." (46: 263.)

From the southeastern corner of St. Paul to Leclair, Hershey believes with other geologists that the valley is pre-glacial. In the vicinity of Dubuque, however, he thinks that the valley is proportionately too small for the stream which it carries, that the preglacial stream flowing past Dubuque could not have been larger than the present Rock river, or possibly no larger than the Pecatonica. The valley is cañon shaped and narrow and the rock floor is about 300 feet below a deep filling of drift. The divide is suggested to be somewhere between La Crosse and Prairie du Chien, particularly where "military ridge" is traversed by the present river. (46:266.)

Hershey believes that the stream north of this supposed divide flowed toward central Minnesota instead of away from it, but that the reversal came early, before the Ice Age, probably at the end of the Ozarkian, by an uplift in the north, or, as an alternative view, it may have "resulted from the disturbance of other drainage systems by the accumulating northern ice. For instance, it is quite possible that the Kansan ice-sheet had advanced across the outlet of the supposed northwardly flowing ancestor of the upper Mississippi river, obstructing its flowage, and after the production of a great extra-glacial lake, turning the drainage of the entire region over the lowest point on the divide which intervened between it and the headwaters of the southwardly flowing central Mississippi river, long before it glaciated the country south of the 'driftless area.' " (46:267.)

Leverett accepts this hypothesis, or at least he quotes it and offers no objections. (64:461-2.)[1]

The question of the preglacial course below Clinton, Iowa, is not yet fully settled. Leverett discusses the problem fully in his writings (58, 60, 62, 63, 64), and lately Carmen has spent some time in the Clinton region, but his paper is not yet published (16). The number of wide channels between Clinton and Muscatine, and the depth of drift renders the problem very complex.

A quotation from Leverett (Monograph 38, pp. 466-7,) will give a fair idea of the location of the preglacial course below Clinton: "Udden's special investigation has led him to the conclusion that the praeglacial line must have been along one of two courses, either southeastward through the Meredosia slough and Green river basin to the Illinois at the bend near Hennepin, or directly westward through the Wapsipinnicon basin to the mouth of Mud creek, and thence southwestward along the Mud creek sag to the Cedar; thence the course may have been by way of the present Cedar and lower Iowa, or more directly southward to the Mississippi just west of the meridian of Muscatine. Udden has collected well data along the Mud creek sag showing that a buried channel occurs there whose rock floor is more than 100 feet below the level of the Mississippi river at Clinton, and perhaps sufficiently low to have carried the drainage of the preglacial stream whose valley has been traced southward to Clinton. The data are scarcely sufficient to fully establish the connection of this channel across the Wapsipinnicon basin, for there are very few deep wells in the basin. Another feature which throws some doubt upon this connection is the narrowness of the deep portion of the channel along the Mud creek sag.

"Turning to the southeastward course, one finds a broad depression or lowland tract leading from Clinton through to the Illinois river. This lowland, except at the outer moraine of the Wisconsin drift in Bureau County, stands only a few feet above the level of the Mississippi, and yet apparently carries a heavy accumulation of drift. The drift is largely sand and there has been no necessity for sinking wells entirely through it.

[1] It may be well to say here that such constrictions in the valley of the Mississippi occur wherever the river crosses resisting strata of rock, such as the Lower Magnesian, and the Galena, Trenton and Niagara limestones, and it may be possible that the river has always been running south, being unable to cut its valley so wide in the more resistant beds. Hershey's theory is interesting but not well established.

They have, however, penetrated 40 to 50 feet without striking rock. The bed rock gradually descends from each side toward the middle of the lowland, and some of the creeks coming into the lowland occupy large and deep channels which have been only partially filled with drift. This rather throws the balance of evidence in favor of the view that the preglacial stream flowed southeastward into the Illinois.

"It should be observed that in case the southwestward route proves to have been the course of the Mississippi, the present line of the stream departs from it only a few miles and enters the same old valley below Muscatine, which it occupies above Clinton. But in case the southeastward route proves to have been the preglacial course from Clinton, the preglacial valley above Clinton finds its continuation down the Illinois instead of down the Mississippi, and the present Mississippi passes from one drainage system to another in its course between Clinton and Muscatine."

Carmon gives many more interesting details, but he concludes with Leverett and Udden: "It is quite possible that in one or the other of these courses the preglacial Mississippi flowed. Both appear to have rock floors to carry the waters of the streams which excavated the Mississippi valley above Clinton, but the data are not complete enough to allow us to decide which of these two courses was the real one" (16). Carmen gives an interesting discussion of the changes produced by each ice invasion upon the Mississippi and a reading of this will help detract from the complexity of the situation in this region.

From Muscatine southward the Mississippi is flowing in a broad preglacial channel except for a few miles above Keokuk, Iowa, where it is flowing in a post-glacial gorge known as the Lower Rapids (63). The old drift-filled valley which has been studied by C. H. Gordon (41), is about twice as wide and 100 feet deeper than the present valley, and lies to the westward in Lee county, Iowa[2] (Fig. 1). Below Keokuk the Mississippi follows the preglacial channel.

Not much space can be devoted to a discussion of the tributaries because the map shows the ones that can be mapped with any certainty, and the reference in regard to each one are full.

Regarding the preglacial history of the Minnesota valley, Upham says (131): "There is evidence . . . . in the terraces of modified drift

[2] Leverett also gives a map and cross sections of this channel. See bib. 62, 63, 64; also J. E. Todd, 114.

along the Minnesota valley, that in large part its erosion was effected in preglacial time and during stages of retreat and readvance of the ice-sheet previous to the final departure." In an earlier article he says that the valley was eroded in the Lower Magnesian and Calciferous formations, before the Cretaceous subsidence, was re-elevated, and, in the first principal epoch of glaciation, covered with a "thick, unbroken, moderately undulating expanse of till" and partly re-excavated by an interglacial stream which, guided by the slope determined by preglacial erosion, coincides along much of its way with the old valley eroded in these strata before the Ice Age (119:109).

The St. Croix river has been discussed by Berkey, R. T. Chamberlin (18), Elftman (30), and Upham (121, 132) and others. Chamberlin thinks the preglacial course from the Dalles of the St. Croix was east to the preglacial Apple river; while the other writers would have it to the westward. The streams of the driftless area in Wisconsin, Minnesota, Iowa and Illinois are preglacial (20, 45-47, 64).

The Wisconsin river is in the preglacial channel below Prairie du Sac. Below Kilbourn City, according to Salisbury and Atwood (89), the preglacial course is east of the present stream, through the Lower Baraboo Narrows, and the Devils Lake Gap of the quartzite ridges on either side of Baraboo, Wisconsin. According to Fenneman (33), a preglacial tributary of the Wisconsin passed northwest through Kegonsa and Mendota lakes. Fenneman finds sections of preglacial channels marked out by the lake basins in southeastern Wisconsin, as shown on the map.

In Illinois, outside of the thick Wisconsin drift which obscures the preglacial valleys of the northeastern part of the State, the preglacial valleys can be fairly easily traced. Outside of the triangular area whose vertices are at Clinton, Hennepin and Rockford, the directions of the present and the preglacial drainage systems are coincident. In this triangular area, the changes have been considerable (62, 64). The preglacial valley of Rock river from Janesville, Wisconsin, to the edge of the Wisconsin drift southward is easily traced, but beyond that the drift rises 100 feet above the preglacial bluffs and its course can be traced only by borings. Its bed is found to be a little lower than that of the Mississippi to the west, descending 210 feet in a distance of 100 miles south from the Wisconsin border. It probably was tributary of the preglacial Mississippi if that river joined the present Illinois.

Chamberlin (19), Upham (125, 128), and Spencer (94) have postulated a preglacial outlet of Lake Michigan through Illinois to the Mississippi, but no such channel has been found. Cache basin in southern Illinois is interesting, because it may be a portion of the preglacial Ohio, as deposits of clay indicate, but why or when it was abandoned is not known (64).

A glance at the map of Iowa shows a correspondence in location and direction between the preglacial and the modern drainage lines. The geological survey of the State of Iowa is not yet completed. The breaks in the preglacial valleys on the map indicate either that the river is not running in a preglacial channel or that it has not been studied. Space will not permit a detailed statement as to which of these two facts is indicated, but a study of the references will make it clear.[3] In the eastern part of the State the preglacial drainage has been obscured by drift and the flow of the temporary interglacial Mississippi across them, while in the northwest the drift alone has defaced the ancient valleys.

In Missouri but little study has been devoted to the preglacial conditions of the State. J. E. Todd (111) has given the following summary of the preglacial drainage in the Missouri Geological Survey: "The Kansas River may have flowed at a higher level, which is indicated by the Weston rapids, and it may be guessed that its course was eastward as far as Chariton County, then possibly northward by the buried channel found in Linn County and Putnam County, although that channel may not be deep enough. All that is now known is that there were deeper channels in Iowa whose beds are lower than the bottom of the present channel of the Missouri river near New Frankfort. Reference is made to the Washington channel discovered by Calvin, and further discussed by Bain. The La Mine and its tributaries may have flowed north and joined it. The Osage and Gasconade may have similarly gone northeast into the valley of the Illinois, the former by way of the valley of the Auxvasse or Big Muddy to the valley of the Salt River and northeast, passing somewhere near Quincy, the latter by the lower course of the Missouri. It may be considered more likely by some that the Kansas river passed Moberly and joined the Osage, or that all these streams may have had nearly their present courses to the present junction of the Osage and Missouri[4]."

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[3] See bibliography, 7, 12, 15, 41, 71, 81, 90, 103, 118, 139.

[4] For references on the tributaries of the Mississippi see: 1, 2, 3, 7, 8, 14, 15, 16, 25, 30, 33, 41, 44, 45, 46, 57, 58, 62, 64, 68, 70, 71, 81, 90, 103, 118, 146.

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PREGLACIAL VALLEYS
WABASH & LOWER OHIO DRAINAGE BASINS
PREGLACIAL VALLEYS
EDGE of WISCONSIN DRIFT
EDGE of ILLINOIS DRIFT
COMPILED BY
HARRY M. CLEM.
LA FAYETTE
COVINGTON
CRAWFORDSVILLE
SUGAR CR.
RACCOON CR.
TERRE HAUTE
SPENCER
GREENUP
NEWTON
EMBARRAS R.
WABASH R.
W. WHITE R.
E. WHITE R.
LITTLE WABASH R.
PATOKA R.
PIGEON CR.
CARMI
OHIO R.

THE PREGLACIAL DRAINAGE OF THE BASIN OF THE WABASH AND LOWER OHIO.

About one-half of the drainage basin of the Wabash river is so deeply buried under glacial deposits that there is very little similarity between the modern watershed and the watershed of the preglacial streams that discharged through the lower course of the Wabash. The preglacial rock surface was probably very rough, for the drift varies within short distances from a few feet to over 200 feet in depth.

The Wabash river at Lafayette is flowing in its original channel. Below Lafayette the preglacial channel runs westward and then southward, meeting the present Wabash at Covington. Below Covington the present river follows the ancient channel. Nothing is known of the upper portion of the preglacial Wabash above Lafayette. A study of the drift covered rocks reveals a divide extending south along the west side of Lake Michigan, and curving to the east into Indiana. It is from 100 to 200 feet above Lake Michigan and is deeply sculptured by preglacial streams and thoroughly drift covered. It has been suggested that the Lake Michigan basin was the headwater portion of the Wabash in preglacial time. On this point Leverett says (62): "The headwater portion of the Wabash stream forming the preglacial Wabash may prove to have been in the Lake Michigan basin. But if so the connection with the Wabash is through a very much narrower trough than that occupied by Lake Michigan. Borings at both North Judson [497 ft.], Winamac [490 ft.] and Monticello [467 ft.], Indiana, situated near the line connecting the heads of Lake Michigan with the preglacial valley at Lafayette, go to a level about 100 feet below the surface of Lake Michigan before entering rock. But within a few miles east of this line rock ledges have an altitude as great as the surface of Lake Michigan, while immediately west of this line they rise 90-125 feet above that level. This trough can not have, in the vicinity of Monticello, a breadth of more than ten miles. Monticello is situated near the middle of the trough. The probabilities are, therefore, against the existence of a much deeper channel in it."

Leverett (65) suggests that the old channel which passes into Grant County from Ohio may be a headwater portion of the preglacial Wabash. The modern Wabash has not completely excavated the ancient valley to its full width above Terre Haute, but below that city the excavation is more nearly complete.

Not much need be said about the tributaries of the Wabash, for Leverett has very fully discussed them. The details have not been worked out, and what is known was that most easily determined. Usually it is the lower portions of these streams and the lower portions of their tributaries that are well known, the headwaters being usually post-glacial and the preglacial valleys covered with drift.

The course of White river below the north line of Greene county, with slight exception, is so completely covered with drift that the course of the preglacial stream can not be ascertained. For a few miles below Martinsville the present stream follows a preglacial valley. The river below Spencer flows for a few miles in a narrow, shallow channel among the hills and ridges, there being no definite preglacial drainage lines to control its course. It occupies a preglacial valley from the mouth of Raccoon creek down to Worthington, where it joins a wider valley two to two and one-half miles wide, which trends south. From this point to its mouth, the course of the stream is nearly coincident with a broad preglacial line.

Bean Blossom creek, which Leverett has not included in his map of the preglacial drainage of Indiana, is undoubtedly preglacial. This is the conclusion of Dr. E. R. Cummings and V. F. Marsters, both of Indiana University, who have worked in this region (69).

The Patoka is very interesting on account of the fact that it is a composite of the headwaters of four different stream systems. For short distances it follows a preglacial channel and then it suddenly crosses rock surfaces which were formerly cols between the preglacial streams. The three upper stream systems emptied northward in preglacial time into the White river. During the advance of the Illinois ice-sheet the mouths of the stream were dammed, and lakes were formed. The water in the upper or eastern lake flowed into the next west over some low sag in the divide and this into the third. Whether the lake drained south over a sag into the Ohio or drained westward to the Wabash through some sub-glacial channel is not settled, but Leverett inclines to the latter (64: 101-2).

The Ohio river (65: 183) below Madison is thought to be preglacial through its entire course along southern Indiana, except probably for a short distance at Louisville, as J. Bryson (12) and C. E. Siebenthal (91) have discovered. This is Leverett's conclusion also, but he says further, "A course about as direct is found in a line leading west from Madison, Indiana, along the Muscatatuck, to the East White and White rivers and thence down the Wabash to the Ohio. That there was an ancient westward drainage along the East White river is shown by the presence of Tertiary gravel near Shoals, Indiana, that was brought from the east. But the East White has a smaller channel than the neighboring part of the Ohio, and no channel has been discovered near Madison to connect the Ohio with the Mascatatuck Valley. It, therefore, seems a less favorable course than that down the Ohio" (65: 112).

Both Tight and Leverett agree in placing the head of the preglacial lower Ohio near Madison, Indiana, thus making it a very humble stream compared with the conditions of today.

THE PREGLACIAL DRAINAGE OF THE BASINS OF THE UPPER AND MIDDLE OHIO.

Much work has been done in this basin, and much has been written about it, and maps of local areas have been made to cover most of the State, but no general map has ever been compiled. The bibliography, as is apparent, contains a great many excellent references to this region. Leverett (65) and Tight (109) give the most complete discussion of the subject, and several other geologists have carefully discussed limited areas of the basin; and in view of the fact that so much has been written on the subject only a few necessary points will be given here.

The Ohio river is remarkable in many respects, for it presents much variety in width, depth and other characteristics. The valley varies in width from six miles, where the walls are low and gentle, to one mile, where steep bluffs enclose it, and its depth ranges from less than 100 feet to 800 feet. Its bed presents a succession of riffles where its channel runs over rock and shoals where the bed is upon a filling often 75 feet deep. The number of narrow places where the bluffs are steep is remarkably large, as is shown on the maps (Pls. IV, V) by the term "col" and at such places the valley is young. Between the cols the present valley is frequently crossed by old, wide valleys that extend for miles on either side. Many of the tributaries, especially below Portsmouth, enter in opposite directions to their general course and many that rise close to the main river, flow around for miles before entering, a fact indicating the recent origin of the Ohio (109: 34). Much of the same may be said of many of the tributaries, such as the Muskingum, Hocking, and the Allegheny, for they are, too, "things of shreds and patches," having been produced by the union of portions of various stream systems.

The location of the primary divide, if the preglacial drainage lines have been established correctly, can be followed in a general way by a glance at the maps (Pls. IV, V). The portion of the divide, and the most important portion, between the Wabash and Erie basins has not yet been satisfactorily located. Upon its accurate determination depends most of our knowledge of the outlet of the drainage of southern and southeastern Ohio. Some general facts concerning it will appear in the following discussion. From near Mt. Vernon east and southeast to New Martinsville the divide is well located, and the area northeast and north drained to the northward. The present Ohio is seen to fall into two divisions on this basis.

The portion of the Ohio above New Martinsville reached some northern outlet by three different streams (Pl. V). These are easily located, with a few minor exceptions, for the preglacial cols are usually apparent. Carll (17) called the attention to a narrowness of the Allegheny valley at Thompson's gap and shows that the rock floor of the valley, now covered with drift, sloped northward from the divide, and he concluded that the headwaters of the Ohio once drained northward by this valley. He concluded that the outlet was through the Cassadaga valley, but Chamberlin and Leverett made later studies, found the Cattaráugus creek valley the deeper and more direct route to Lake Erie and concluded that the outlet was by that valley (65: 129-30; 21: 101: 159-60).

Another prominent col just north of Parker separates another section of the Allegheny which included the Allegheny to a little below Oil City. French creek reversed to Meadville and an old valley continuing northward to some preglacial valley in the Erie basin were the main stream in the system, for here is an old, wide rambling valley in which Cussewaga creek flows south to join French creek. Leverett accepts this outlet, showing that the drainage could not have been up French creek above Martinsville, because of a col in French creek valley a few miles northeast of Meadville (65: 134-8).

The next lower section of the preglacial system, whose main stream was the Beaver reversed, and the Grand, is variously known as the Spencer (35), Old Lower Allegheny, Pittsburg (109) and Grand river (21). It has been well studied and most authors agree upon its course. The drift is deep north of the source of the Beaver; but the old gradation plain slopes north to Sharon and then upward farther north. A depression descends westward to Youngstown on the Mahoning. Borings at Niles and Rome reached level at 70 feet above Lake Erie, showing that the old Grand valley grows deeper in the north (65: 149-51).

They are marked off by the meridians of New Martinsville and Columbus and include a mass of detail that, in most cases, is very difficult to map from the text. The area south of a line between New Martinsville and the mouth of Newark river has been studied thoroughly by Tight and mapped in detail (Pl. V and 109) and well discussed. The changes here are quite profound but they can be read with little difficulty.

Theh Muskingum has offered much difficulty to its own solution, especially within the deeply drift-covered areas. Leverett (65: 158-65) gives the most concise summary of the preglacial conditions of the basin, but Tight (109, Pl. I) gives a similar general outline, and with local writers discusses the region.

The Blue Rock col is sufficiently plain to separate that part of the present stream into north flowing and south flowing portions. The north flowing part might have gone north along the present Muskingum or northwest up the Licking, but Leverett favors the latter (65: 161). Tight is especially responsible for the section drained by the Licking reversed and the preglacial Newark (104: 152, Pl. I; 91: 160) and of Vernon river.

Much difficulty was experienced in determining the location of the preglacial channel which carried the drainage of the present Muskingum after it reaches the headwaters of the present Rocky river. Todd (117), a local writer who has a paper on the preglacial drainage of the Rocky basin and an area south, favors an outlet down the preglacial Rocky, but Leverett (65: 165) believes that it flowed east into the old Cuyahoga (Pl. IV), although he admits that the evidence of a slope in the rock floor in that direction is meager. He also favors the idea that the upper Tuscarawas was continuous with the preglacial Cuyahoga.

The system of preglacial drainage (Pls. IV, V) collected into Portsmouth river—the lower Scioto reversed—is fully discussed by Tight, Leverett and others and is established. Newark, Vernon and Portsmouth rivers united somewhere southwest of Columbus, but it is not well known just where. After the union of these rivers the direction of their united valleys is not yet determined. Leverett (65: 103-4) says on the question: "Four possible courses were suggested for the discharge from the southern end of the Scioto basin: First, southward, down the Scioto from Waverly to the Ohio and thence down the Ohio; second, northward, along the axis of the Scioto basin to Lake Erie; third, northwestward across western Ohio, along one of the several deep valleys brought to light in that region by the oil and gas wells, eventually to the low tract on the lower course of the Wabash or the basin of Lake Michigan; fourth, northeastward past the Licking reservoir and an old valley east of Newark to the Muskingum at Dresden, and thence northward along or near the present valley of the Muskingum, Tuscarawas, and Cuyahoga to the basin of Lake Erie at Cleveland." (65: 102-4.) Leverett later found an oxbow channel at Lucasville, which seemed to testify strongly against a southern discharge, and a divide now crossed by the Tuscarawas between Zoar and Canal Dover, which renders a northeast discharge impossible. It seems worth while to quote Leverett concerning the difficulties of the other two routes: "The northward route along the axis of the Scioto basin encounters a general rise in the bordering plain of about 200 feet in the 100 miles between the south end of the basin, near Chillicothe, and the continental divide near Marion, north of which there is an even greater descent to the Lake Erie basin. If the course of drainage was northward across the divide, and if the divide has not suffered recent uplift, there must have been channeling in it to a depth of about 300 feet. That an axis of uplift exists in this part of the continental divide is shown by the arching of the rock formations over it; but its extent and its date are not yet determined.

"The northwestward route leads across the limestone belt on the west side of the Scioto basin, whose general level is about 200 feet above the continental divide at the north end of the basin and 500 feet above the gradation plain near Chillicothe. To pass through that region the channeling would be so much greater than is required for a northward course along the axis of the basin, that one can scarcely resist ruling out the northwestward course. Yet from what is found on the lower Ohio, where the stream passes directly across the low Devonian shale area into the knobstone and sandstone formations that now stand much higher, such a ruling may be unwarranted. The presence of the low basin occupied by Lake Erie offers an additional argument in favor of the northward route. This basin would be reached by that route in less than half the distance required to reach a similar low track in the Wabash region, or the Lake Michigan basin by the northwestward route. Each of these routes falls within regions so heavily covered with glacial deposits that the course of the channels can be traced only by means of borings, and these are so few and so poorly distributed as to be inadequate to our needs."

Tight favors a northwestward discharge of the Portsmouth river and so maps it in Plate I, Professional Paper, No. 13 (109).

Bownocker has studied the deep borings of west central Ohio and finds evidence of a deep channel running from Anna to Celina, north to Rockford and west into Indiana, as far as Grant county, where no borings by which it may be traced are found (10, 11). This old channel may be a continuation of the preglacial stream in question (Portsmouth river), and Leverett suggests that it may be a tributary of the Wabash (65: 183-4; see 109, p. 23 and Pl. I), but adds: "The size of the valley indicates that it drained at most only a few counties of western Ohio."

Between Manchester, Ohio, and Madison, Indiana, the Ohio crosses three cols, which means that it is the united parts of four basins. The Licking and Kentucky rivers are thought by both Bownocker and Fowke to have been united to form a single stream at Hamilton. Fowke and Tight think that from Hamilton it flowed northward along the Great Miami reversed. Leverett, who opposes the idea, states, "It is probable that the old drainage south from the latitude of Dayton followed nearly the course of the present line to the Ohio. . . . The old Ohio was entered by the Great Miami near Hamilton. The latter stream makes slight departures from the line of the old Ohio below Hamilton, the old Ohio channel being in part farther west than the Great Miami." (65, p. 184.)

Fowke believes that the old channel between Hamilton and the mouth of the Kentucky was eroded by the Kentucky river, instead of the Ohio. He says: "In other words, that stream, instead of following the present Ohio as it does now, or flowing across Indiana, turned to the east and north and joined the Licking at Hamilton. There is no other channel through which it could have gone. . . . From Hamilton northward the old river bed is filled with drift and has not been traced. There can be no doubt, however, that it joined the old Kanawha (Chillicothe) north of Dayton, probably in the neighborhood of Piqua." (36). The preglacial head of the Ohio is by this theory placed at Madison, Indiana.

The present course of the Ohio is due to the action of the ice-sheet which dammed the north flowing streams, forming lakes in the basins which overflowed at the lowest point in the divides between basins to the next lower neighboring basin. The lakes endured sufficiently long for the present Ohio to establish itself in the course which it now follows (36, 109).

THE PREGLACIAL DRAINAGE OF THE BASIN OF THE GREAT LAKES.

The Great Lakes have been so closely connected with the glacial history of the Mississippi basin, their origin is so closely connected with the preglacial Mississippi basin that it seems well to add a chapter to present briefly what is known about their preglacial history.

Newberry was one of the earliest writers to state the theory now so universally believed, that the antecedent of the Great Lakes was a great river system. According to him the first suggestion of the notion was given by deep borings in the valley of the Cuyahoga at Cleveland, which is a deep valley filled with drift (79). As early as 1882, in a summary of his work, Newberry mentioned, among other points, that he believed that "an extensive system of drainage lines which once traversed the continent, had been subsequently filled up and obliterated by the drift of the ice period." (79.)

Newberry thought the outlet of the lakes through Ontario was through a preglacial valley now occupied by the Mohawk river, and so mapped it in 1878. Spencer took exception to this idea, saying, "The Mohawk course will not answer, as the geological survey of Pennsylvania has shown that at Little Falls, Herkimer county, the Mohawk flows over metamorphic rocks." (79.) Lesley added that this rock divide was 900 feet above the floor of Lake Ontario.

Spencer began the study of the connection between Lake Erie and Lake Ontario before 1880, and in 1881 announced that he had found that the connection was through the Dundas Valley (94), and Newberry at once declared that he himself had prophesied the location of the connection where Spencer found it. Spencer thought that the outlet of the preglacial valley occupied by Lake Ontario could not be the St. Lawrence river, because the bed of the St. Lawrence river is of solid rock (94), nor the Mohawk, because of the rock divide at Little Falls. The channels through northern New York were unimportant and would not answer. The Seneca basin and the Susquehanna seemed available at first, for the deepest part of Lake Ontario is north of Seneca Lake, but too much subsidence would be required (94). After studying the beaches about Lake Ontario and noticing that they were tilted to the west, Spencer announced that the preglacial outlet was down the St. Lawrence (97, 100). Later he worked out the system of channels which is shown in Fig, 4 (100, 101). Spencer suggested that Lake Michigan had a preglacial outlet to the south or southwest (93).

Upham (125, 128) took exception to Spencer's interpretation of the direction of the Laurentian preglacial drainage, and offered the theory that "A great trunk stream flowing south along the bed of Lake Michigan drew its chief tributaries on one side from the basins of Lakes Huron, Erie and Ontario, and the other side from the basin of Lake Superior." He held that during the latter half of the Cretaceous period nearly all the drainage area which now forms Minnesota and the drainage basin of the Missouri river was depressed and covered by the sea, while the contiguous area forming the Great Lakes region was dry land and continued so up to the coming of the Ice Age. The divide separating this area from the basins draining to the Atlantic, extended "along the Allegheny mountain belt and directly onward northeasterly to the Adirondacks, turning thence northwesterly across the Ontario highlands . . . to the present height of land north of Lake Superior." Spencer's preglacial stream system was, therefore, probably limited to the headwater streams now represented by the Lake Champlain basin and the Saguenay and Ottawa rivers.

Lately Grabau (43) has interpreted the preglacial drainage of the Great Lakes region in a manner different from Spencer and Upham. His theory briefly stated is this: The old surface of the pre-Cambrian rocks was worn away by long continued erosion and there were laid down upon them horizontally, but unconformably, the newer beds of Ordovician and Silurian rock. Then followed an uplift greater in the north, tilting the new beds southward with a dip of about 25 feet per mile. Following the uplift was a period of erosion, wherein the region "suffered an enormous amount of denudation, having been brought to the condition of a low nearly level tract or peneplain a little above sea level." Then the surface was submerged and beds of Devonian limestone, shales, and sandstones were laid down over it. The sea bottom became dry land and another cycle of erosion began. The uplifted beds formed a "broad essentially monotonous" coastal plain sloping gently southward. Consequent streams flowed southward down the slope. The great master streams developed were the Saginaw, Dundas and Genesee rivers, and probably some of the Finger lake valleys. As erosion proceeded, the sloping harder beds endured and cuestas were formed, having their steeper slopes to the north. Along the foot of the escarpments the subsequent streams flowed to the master streams. The Buffalo, the Tonawanda and other large tributaries coming in at right angles to the consequent streams are the subsequent streams and some of their valleys are now the basins of the Great Lakes.

Short gullies, or tributaries to the subsequent streams, called obsequent streams, worked headward into the cliffs of the cuestas. Such a stream was the St. David's gorge, which, however, was not the preglacial Niagara, as was once believed by Scovell, Pohlman (84) and others.

The direction of preglacial drainage postulated by the theory above is in accord with the theories of Upham (128), Westgate (137), Russel (88), and also A. W. G. Wilson, who has worked the preglacial drainage of the region east and north of Lake Ontario in detail (140) (Plate VI).

Cross Fertilization Among Fishes.

By W. J. Moenkhaus, Indiana University, Bloomington, Indiana.

CONTENTS.

INTRODUCTORY.

In the following pages I wish to record the more important results of my experiments in the cross-fertilization of fishes. These have been in progress more or less continuously since 1898. These experiments were originally undertaken with quite another object in view, namely, for inheritance and cytological studies. A survey of available nearly related forms was made that would successfully hybridize for variation and inheritance studies. Another purpose was the hybridization of forms with different shaped chromosomes, so that the behavior of the latter could be followed in development. It soon developed that the possibility of cross-fertilizing fishes was very much greater than had hitherto been supposed. This led me to seek all possible combinations of species of whatever relationship that happened to be spawning at the same time, and note the possibility and character of impregnation, the development of the hybrids and the fate of developing embryos.

The writer wishes to express his sincere thanks to Prof. Charles B. Davenport for privileges enjoyed at the Miami Laboratory, Cold Spring Harbor; to Hon. Geo. M. Bowers and Supt. Francis B. Sumner for privileges at the United States Fish Commission Laboratories at Woods Hall, and to the trustees of the Elizabeth Thompson Science Fund for a grant that made it possible incidentally to gather some of the data included in this report.

HISTORICAL.

With one exception, to be noted later, it is possible to impregnate the eggs of any of the species tried, with the sperm of any other species tried, although they belonged to widely separated orders. Isolated instances of equally, or even more distinct crosses have been recorded. Appellöf ('94) made the following crosses among fishes:

Pleuronectes platessa ♀
×
Gadus morhua ♂
Labrus rupestris ♀
×
Gadus morhua ♂

In each of these the species belong to distinct orders. A portion only of the eggs were impregnated. A few showed irregularities in cleavage, and were presumably polyspermic. The European Amphibia have been extensively hybridized by Pflüger ('82) and by Born ('83). The former succeeded in impregnating the eggs of *Rana fusca* with the sperm of both *Triton alpestris* and *Triton taeniatus, i. e.*, an Anuran with a Urodele. The segmentation, however, was irregular so that all the eggs were probably polyspermic. Morgan ('93) succeeded in impregnating the eggs of *Asterias* with the sperm of *Arbacia*. He obtained normal cleavage, the larvæ developing to blastulæ and gastrulæ. His experiments were carefully repeated by Driesch ('98) without result. Mathews ('01) believed Morgan's results were due to parthenogenesis induced by shaking the eggs. Loeb ('03), working with the Pacific Coast Echinoderms, found it impossible under normal condition to fertilize the eggs of *Strongylocentrotus purpuratus* with the sperm of any of the starfish. However, by changing the constitution of the sea water he succeeded in getting impregnations (in some cases 50 per cent.) between *S. purpuratus* ♀ and *Asterias ochracea*. Segmentation was normal; the larvæ developed into blastulæ and gastrulæ, some showing the differentiation of the intestine. Many other experiments in hybridizing fishes have been recorded. These, however, were all between nearly related species, mostly among the domesticated salmonidæ and cyprinidæ. It would not be to the point to pass these in review here. For a good summary of these the reader is referred to Ackermann ('98).

METHODS.

The method of effecting the crosses and the precautions taken to prevent contamination with other sperms, were in all cases essentially the same. The sexes of the same species were kept in separate aquaria. The eggs were expressed into well sterilized watch glasses after which the milt was added. Before adding the milt a sufficient number of eggs were taken from the lot and placed in a fingerbowl of water, as a control. The fertilized lot was also placed in a fingerbowl and allowed to develop there. After the per cent. and character of impregnation was determined and the development well along in segmentation, changes of water sufficiently frequent to insure normal conditions for development were made.[1] All dishes, pipettes, etc., were thoroughly sterilized, first with hot water and then with 95 per cent. alcohol. Notwithstanding the fact that it was found that little danger of contamination existed, the precautions were strictly observed. In not a single instance was there any suspicion that the eggs were not fertilized by the desired sperm.

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[1] I wish to call attention to one defect in the methods of rearing the hybrid eggs. It may be objected that while the rearing of the eggs in the fingerbowl may be satisfactory for Fundulus and some other species it is not normal for a hybrid egg having a sperm from a species that has, for instance, pelagic mode of life during its developmental stages. This unnatural condition may, therefore, in part at least, be responsible for the failures in the development, or even the particular stages at which development ceases. This objection, so far as we know, may or may not be of value. I see no way to avoid this experimental error, since it is not practicable to cater to the demands of one of the parent species without, theoretically at least, infringing on the other. It may be said, however, that many of the species, especially those on which most stress has been laid, have been successfully reared by this method, e. x., all the species of Fundulus, the two species of Sticklebacks, and the two species of Menidia. It is the belief of the writer that this objection may be disregarded.

DESCRIPTION OF CROSSES.

In the following detailed description of the various crosses only such details are included as seemed valuable. Certain of the crosses were kept under observation much more closely than others, and these are more completely considered. It seemed desirable, however, to list the other crosses made, giving brief notes when such seemed worth while. A complete list of all the crosses made is included in Table 9.

Fundulus heteroclitus, female,

×

Menidia notata, male.

This cross was made more frequently and studied more completely than any of the others. A description of the chromosomal behavior has been published by the writer ('94). I included there also a brief description of the development. For the sake of completeness this may be incorporated here. The percentage of eggs fertilized varies from 70 to 93. Actual counts were not made in all the experiments. The percentages in four determinations were as follows:

Experiment	24b	87 per cent.
"	25b	80 " "
"	24b	93 " "
"	126	70 " "

Of the eggs impregnated, approximately 50 per cent. are quite constantly dispermic. Very few are polyspermic so far as can be ascertained by the mode of cleavage. The dispermic eggs never go further than to the close of cleavage. The normally impregnated eggs go through the cleavage stages in a perfectly normal fashion. This is true both for the form and the rhythm of cleavage. In the following table is given a comparison of a lot of hybrid eggs with a lot of normals. The eggs were taken from the same female, fertilized at the same moment and kept under similar conditions. The observations were made at the same time on both lots of eggs and the stage at which each was found was recorded as accurately as possible.

TABLE 1.

TIME OF OBSERVATION.	FUND. × FUND.	FUND. × MEN.
9.10 P. M., June 26.[1]	In 2 cells.	In 2 cells.
9.40 P. M., June 26.	Beginning 4 cells.	Beginning 4 cells.
10.00 P. M., June 26.	Completion 4 cells.	Completion 4 cells.
10.15 P. M., June 26.	Beginning 8 cells.	Beginning 8 cells.
10.20 P. M., June 26.	Well begun on 8 cells.	Well begun on 8 cells.
10.30 P. M., June 26.	In 8 cells.	In 8 cells.
11.00 P. M., June 26.	Beginning 16 cells.	Beginning 16 cells.
9.00 A. M., June 27.	Well along in segmentation.	Well along in segmentation.
9.00 P. M., June 27.	Well begun on gastrulation.	First trace of gastrulation.
9.00 A. M., June 28.	$\frac{2}{3}$+over the yolk.	$\frac{1}{2}$ or less over the yolk.
3.00 P. M., June 28.	Blastopore closed.	$\frac{2}{3}$ over the yolk.
5.30 P. M., June 28.	Blastopore closed, the embryo long and narrow.	Blastopore closing or nearly losed; embryo much shorter than normal.
9.00 A. M., June 29.	Embryo with optic vesicle.	Blastopore closed, embryo short, no optic vesicle; apparently dead.

[1]Eggs fertilized at 7 P. M., June 26.

From this table it will be seen that the hybrids fall behind the normals in their development. This becomes apparent only in the later stages. In the latter stages considerable irregularity in the rate of development obtains. Usually in a lot of eggs most of which have the blastopore just closed, some eggs may be found that have just entered upon the germ-ring stage. Others may be variously further along. The number of such tardy eggs is usually small. These eggs may stop their development at various stages with consequent shortened embryos and incomplete blastopore closure. In this aborted condition they may live for days, forming pigment both in the embryo and in the yolk. This mass of cells may even develop a heart and ear vesicles. The heart beats for days without, however, handling any blood. From such condition to one where the embryo seems at first to be practically normal there are all stages. The great majority of the embryos die at a condition where the blastopore is closed, the embryo is laid down, though somewhat short, with pigment developed but no heart, eyes, etc.

Some of the embryos, under favorable conditions, develop considerably further. In the more successful of these the yolk becomes highly pigmented with both kinds of chromatophores. The same is true of the embryo. There is an attempt at pattern formation, showing bilateral symmetry but lacking any marked uniformity in the different embryos. A small proportion of the embryos may show only the reddish-brown pigment cells with complete absence of melanaphores. Such embryos are of a strikingly brilliant reddish-brown color. The black pigment may be deposited in the eyes, however. The body of the embryo becomes considerably elongated, though never as long as the normals. The muscle segments are well developed; the vacuolated notocord can be seen and the indications of the vertebral spines can in some cases be made out from a surface view. I have not seen the dorsal and caudal fin-folds developed, except in a very rudimentary way; the pectorals, on the other hand, may be present, and in some embryos are larger than normal. The eyes are at first normally formed, showing as normal optic cups and a well developed lens, and having the normal size. Pigment begins to be deposited much as in the normal, but does not become as abundant. The eye does not keep pace, however, with the normals, so that it finally becomes too small, too slightly pigmented and often lying too low as well as too far forward. The ear vesicle may become very large, appearing as a prominent bulb on either side. The otoliths can be plainly seen. I have seen no indication of a mouth. The brain vesicles form in the earlier stage of the development of these hybrids. Later the brain shows cavities varying in size and regularity, but quite different from the normals. The peri-cardial cavity usually becomes quite large with a volume one-fourth or one-third the size of the whole yolk sphere. The heart becomes often much drawn out. In other cases it is relatively short and may show regions of differentiation. This pulsates vigorously, the wave going in the proper direction. I obtained a single embryo that succeeded in establishing a circulation so that blood was handled by the heart and circulated through the embryo and over the yolk. This circulation lasted for three days, when the vessels became clogged. The heart continued, however, to beat without moving any blood. The usual condition is to have no circulation established. Isolated regions on the yolk show capillaries with colored contents, but no movement of the latter obtains. In the embryo, likewise, lakelets of blood form, a favorite place being in the median ventral part of the tail just posterior to the yolk. I have kept embryos alive for twenty-nine days. The yolk may become reduced to one-half or more in amount. The embryo will not hatch.

Medinia notata, female.

×

Fundulus heteroclitus, male.

The reciprocal of the preceding cross was made four times. The percentage of impregnation does not seem to run as high as in the reciprocal cross. Thus:

Experiment	23b	14 per cent.
"	27	Small per cent.
"	130	88 per cent.

It is probable that the lower percentages of impregnation in experiments 23b and 27 have no significance. The experiments show that under favorable conditions a very high per cent. of impregnation is possible—a condition probably varying but little from the normal.

The condition of dispermy present to such a large extent in the reciprocals does not obtain in this cross.

The rate of development during the earlier stages was the same as that of the normal. The process, however, showed a slowing during the later cleavage stages, as was shown by the normals pretty generally entering upon the germ-ring stage, earlier than the hybrids. Inspection of Table 2, in which the stages of the normals and hybrids are placed in parallel columns, will show that from this point the developmental processes were considerably slowed. Thus, when the blastopore is closed, and the eyes are present in the normals at 4 p. m. 6/15, the hybrids have reached only the stage where the embryo has crept ⅓ to ⅔ over the yolk.

Table 2.

Time.	Menidia notaba × Menidia notata.	Menidia notata × Fundulus heteroclitus.
6.05 P. M., June 12.	Fertilization.	Fertilization.
7.35 P. M., June 12.	Begin. 2 cells.	Begin. 2 cells.
7.35 P. M., June 12.	Close of 2 cells.	Close of 2 cells.
8.50 P. M., June 12.	Begin. 4 cells.	Begin. 4 cells
9.15 P. M., June 12.	Close of 4 cells.	Close of 4 cells.
9.26 P. M., June 12.	Begin. 8 cells.	Begin. 8 cells.
10.08 P. M., June 12.	Close 8 cells.	Close 8 cells.
10.20 P. M., June 12.	Close 16 cells.	Close 16 cells.
10.35 P .M., June 12.	Close 16 cells.	Close 16 cells.
11.05 P. M., June 12.	Close 32 cells.	Close 32 cells.
5.55 A. M., June 13.	Early cleavage.	Early cleavage.
9.00 P. M., June 13.	Germ ring.	Late cleavage and germ ring.
9.00 A. M., June 14.	Germ ring to ½ over yolk.	Early gastrula.
1.30 P. M., June 14.	Begin. gastrula to close of blastopore.	Early gastrula to ½ over yolk.
4.00 P. M., June 15.	Blastopore closed and eyes present.	⅓ to ⅔ over yolk.
2.00 P. M., June 17.		Emb. incompletely formed, optic ves. showing.
2.00 P. M., June 18.		No further along.

The development during the cleavage stages, similar to the reciprocal cross, proceeds normally. It is only in the subsequent stages that the effect of hybridization manifests itself. This shows itself for one thing in the great irregularity of the stages at a given moment. At a time when some of the eggs have proceeded as far as they will go, the greater number of the eggs are in all stages, back to the close of cleavage. This is much more marked than in the reciprocals. It is possible, however, that this is a function of the egg, since even the normals show a considerably greater number of stragglers than do the normal Fundulus eggs. The eggs of this species are evidently less hardy and thus may lend themselves less perfectly to the methods used in rearing them. When development finally ceases the embryos are, for the most part, nearing the closure of the blastopore, the more successful ones showing an embryo with the optic vesicles, but with the body shorter than the normals. The conditions are not essentially different from that described for the reciprocals, except that, as a whole, the development gives out at a somewhat earlier period. This, as already indicated, is possibly due to the less hardy condition of the Menidia egg.

Fundulus heteroclitus, female.

×

Menidia gracilis, male.

Menidia gracilis is distinguished with difficulty from Menidia notata, except in its smaller size. Three experiments were made with this cross.

The percentage of eggs impregnated was as follows:

Ezperiment	119	93 per cent.
"	501	About 5 per cent.
"	503	81 per cent.

In experiment 501 the wet method was employed which probably is responsible for the low percentage. The controls with normal Fundulus eggs showed a correspondingly low per cent. of impregnation.

The number of dispermic and polyspermic eggs was considerably less than in the cross with Menidia notata. In experiment 503 the per cent. was thirteen, about two-thirds of which were dispermic.

The rate of development and the stage at which it stops is similar to that of the cross with Menidia notata. As a whole the number of eggs that successfully effect the closure of the blastopore is greater and the embryos vary considerably less in their lengths, approaching more nearly to the normals. The rudiments of the eye are present. The reciprocal of this cross was not attempted.

In this cross many of the eggs stop their development at the closure of the blastophore with the main axis of the embryo laid down. Many of the eggs continue their development to a varying degree and with varying normality. None of them, however, are developed in a perfectly normal manner. Among these embryos which live for a week or ten days, the most grotesque features appear. The yolk and embryo become pigmented, often very heavily, though not normally. On the yolk the pigment cells may be quite large, or quite finely branched, and they are likely to congregate in certain places, instead of having a distribution such as is found on the normal embryo. A favorite place for such congregation is on the surface between the very large pericardial cavity and the yolk where the pigment cells may densely cover the area. In the embryo the distribution of the pigment may be more or less regular. Thus along the dorsal side two rows may appear in the anterior portion, one on either side, these converging into a single median band running well out towards the posterior end. Both kinds of pigment cells, red and black, are well represented.

The heart is always developed in these embryos and usually pulsates quite vigorously. The excessive development of the pericardial cavity which usually appears as a large clear vesicle—sometimes one-third the size of the yolk—has the effect of stretching the heart out to a great length. As a consequence a curious series of modifications obtain in the different embryos, from a relatively normal heart, although always more or less elongated, to strikingly aberrant conditions, in which the pulsating portion of the heart has become associated with the yolk bordering on the lower portion of the large pericardial cavity, and is a mere mass of cells without apparent structure, and connected with the upper border of the pericardial cavity near the embryo, by an extremely slender protoplasmic thread. No lumen can be detected in either portion and the only effect of the rythmical and vigorous pulsations of the lower yolk portion is to stretch this filament, and pull the yolk upwards so that the latter rocks continually. The usual thing is for the heart to develop a cavity in the interior and the peristaltic pulsations pass in the right direction, *i. e.*, toward the embryo. Out of hundreds of such hearts, many of them relatively normal, which I have examined, I have never seen one carrying blood, certainly not blood containing red corpuscles. In regard to the rest of the circulatory system there is very little to say since it fails to develop. I have never seen any indication of bloodvessels, either in the embryo or in the yolk so far as these could be made out by circlulating blood. There is now and then an embryo that shows what seems, from surface view, a little lakelet of blood. No corpuscles, however, can be seen, and I think they are only accumulations of a pigment of some sort. Nevertheless a considerable portion of the yolk substance is absorbed. This is transferred to the embryo by probably the same method as is employed prior to the development of the vascular system.

The body of the embryo is always much too short and appears heavy. The tail may develop to a considerable length, and in the more successful individuals may show the caudal fin-folds with fine radiations. The body lacks regularity of form and outline. Muscle segments develop, plainly marked off by the brown pigment deposits along their borders. The muscle segments are active, shown by the frequent movements of the tail.

The eyes may be developed to varying degrees, or in many embryos there is no indication of an eye. A quite common condition is the appearance of only a single eye. Some of the embryos show an accumulation of pigment cells either in two patches or one, which because of their location and the fact that they are in rather well-circumscribed patches, probably represent the eye. Two eyes are formed in many. These are always located far forward, so that they seem set into the anterior surface of the head. These may be quite large, well pigmented and showing a lens, or they may be smaller, varying to a condition where merely two small pigment areas are located on the very extreme anterior tip of the pointed head.

The ear vesicle is usually formed. In the place where the vesicle should be there is commonly formed, in the older embryos, an enlarged vesicular structure. This, in some cases, is beyond doubt the enlarged ear vesicle.

The embryos gradually die, but the better formed ones have lived for me for ten days after the normals had hatched.

Fundulus heteroclitus, female,

×

Tautogolabrus adspersus, male.

This cross was made five times. The percentage of impregnation may be almost normal, as shown in experiment 36 in the following table:

Experiment	28b	65 per cent.
"	34b	17 " "
"	36	90 " "
"	102b	35 " "

Practically all of the eggs were normally impregnated, a very few of the eggs fell directly into four and six cells. The rate of development was the same as the normals, until the later stages, when the hybrids fell behind, as shown in Table 3. The table would indicate that the hybrids were a little slower in their cleavage, but this is so slight that no value can be placed on it, considering the difficulty in telling exactly the moment when a new set of furrows begin.

Many of the eggs go far enough to form the embryonic ring and the embryonic shield. The protoplasm continues to spread over the yolk until it is encompassed about two-thirds the way, or nearly closed. The embryo, however, does not form in the shield as it should. I have seen many eggs forming the germ ring and embryonic shield perfectly. The protoplasm continues to grow over the yolk, but the embryo fails to develop perfectly. It is usually much too short and often with the blastopore about closed, there has failed to develop any embryo at all in the shield, the latter remaining a mere mass of cells.

TABLE 3.

	FUNDULUS × FUNDULUS.	FUNDULUS × TAUTOGLABRUS.
Fertilization.	9.30 A. M., July 4,	9.30 A. M., July 4.
Begin. 2 cells.	11.17	11.17
Compl. 2 cells.	11.35	11.35
Begin. 4 cells.	11.50	11.46
Comp. 4 cells.	12.20	12.10
Begin. 8 cells.	12.25	12.15
Compl. 8 cells.	12.45	12.40
Begin. 16 cells.	12.50	12.45
Late segment	12.30 P. M., July 5.	12.30 P. M., July 5.
½ over yoke.	12.00 M. July 6.	12.00 M., July 6.
Blast. closed.	12.00 M. July 7.	Had stopped in previous stage. No embryo differentiated.

Tautogolabrus adspersus, female.

×

Fundulus heteroclitus, male.

This cross was attempted but once and the development followed to the 16-cell stage. Sixteen per cent. of the eggs were impregnated. The rate of development compared with the normals is given in the table below:

TABLE 4.

TIME.	TAUTOGLABRUS × TAUTOGLABRUS.	TAUTOGLABRUS × FUNDULUS.
9.30 P. M., July 4.	Fertilized.	Fertilized.
10.30 P. M., July 4.	Two cells.	Two cells.
10.45 P. M., July 4.	Begin. 4 cells.	Close of 2 cells.
10.50 P. M., July 4.	Well along in 4 cells.	Begin. 4 cells.
11.00 P. M., July 4.	Close of 4 cells.	Well along in 4 cells.
11.10 P. M., July 4.	Well begun on 8 cells.	Close of 4 cells.
11.15 P. M., July 4.	Well along in 8 cells.	Begin. 8 cells.
11.30 P. M., July 4.	Begin. 16 cells.	Close of 8 cells.
11.55 P. M., July 4.	16+cells.	16+cells.

Fundulus heteroclitus, female.

×

Tautoga onitis, male.

The percentage of eggs fertilized in the three experiments made was as follows:

Experiment 104	66 per cent.
" 108	40 " "
" 506	26 " "

It is not probable that with perfectly fresh milt the percentage would be higher. I have observed. the sex products of both sexes in this species materially deteriorate upon confinement of the fish, even for a short time. In experiment 506 good eggs were used and perfectly fresh milt in abundance was used. Practically all of the fertilized eggs are normally impregnated. In experiment 506 every impregnated egg was normal.

The development proceeds in the same manner as in the cross between Fundulus and Tautoglabrus. Most of the eggs form a definite embryonic rim and an apparently normal embryonic shield, but even though they may go to the closure of the blastopore, the embryo is always much too short, never exceeding one-half the normal length. They are mostly shorter than this, a mere thickened mass of cells developed in the embryonic shield. In some cases the blastopore is practically closed, surrounded by a broad embryonic rim with the embryonic shield devoid of any embryo.

Fundulus heteroclitus, female,

×

Gasterosteus bispinosus, male.

The percentage of eggs impregnated may be nearly normal, thus:

Experiment 26d..............................86 per cent.
" 105d..............................18 " "

A very few of the eggs may be polyspermic. The details of the development of the hybrid and the normals occur in the table following. It will be noticed that the developmental processes keep apace until the close of cleavage. During the formation of the embryo the hybrids fall perceptibly behind. Most of the eggs go to the closure of the blastopore, although this is accomplished in many eggs only imperfectly. The embryos are largely shorter than the normals. The details of development are itemized in Table 5.

TABLE 5.

TIME.	FUNDULUS × FUNDULUS.	FUNDULUS × GASTEROSTEUS.
2.40 P. M., June 30.	Fertilization.	Fertilization.
5.00 P. M., June 30.	Well along in 2 cells.	Well along in 2 cells.
5.12 P. M., June 30.	Begin. 4 cells.	Begin. 4 cells.
5.57 P. M., June 30.	Still in 4 cells.	Begin. 8 cells.
6.03 P. M., June 30.	Just begin. 8 cells.	Mostly well along in 8 cells.
6.05 P. M., June 30.	Mostly well along in 8 cells.	Well along in 8 cells.
11.00 A. M., July 1.	Toward close of segmentation.	Toward close of segmentation.
12.30 P. M. July 1.,	Late segmentation.	Late segmentation.
1.30 P. M., July 1.	Begin. gastrulation.	Begin. gastrulation.
9.00 P. M., July 1.	½ over yolk.	¼ over yolk.
11.00 A. M., July 2.	⅔ + over yolk.	Mostly ⅓ + over yolk.
12.00 M., July 4.	Embryos formed, brain vesicles, etc.	Embryos formed but no indication of brain vesicles, etc.
12.00 M., July 7.	Eyes formed; tall.	About same as in previous stage.

Gasterosteus bispinosus, female,

×

Fundulus heteroclitus, male.

This cross was made three times, and in one case all the eggs were impregnated. There is the same high mortality usual during gastrulation in these hybrids. Those eggs that laid down the embryo showed the latter very much shortened and the head end very much thickened, many of the embryos appearing to be only head. Rudimentary eyes may form. Details of the development rate, etc., in the normals and hybrids are included in Table 6.

TABLE 6.

TIME.	GASTEROSTEUS × GASTEROSTEUS.	GASTEROSTEUS × FUNDULUS.
1.05 P. M., June 4.	Fertilization.	Fertilization.
4.00 P. M., June 4.	Two cells.	Two cells.
4.30 P. M., June 4.	In 4 cells.	In 4 cells.
4.45 P. M., June 4.	In 4 cells.	In 4 cells.
4.55 P. M., June 4.	Begun on 8 cells.	Begun on 8 cells.
5.15 P. M., June 4.	Close of 8 cells.	Close of 8 cells.
5.25 P. M., June 4.	Begin. 16 cells.	Begin. 16 cells.
6.05 P. M., June 4.	In 32 cells.	In 32 cells.
9.15 A. M., June 5.	Late segmentation. Disk begin. to spread.	Late segmentation. Disk less spread than in normals.
11.40 A. M., June 5.	Germ ring well formed.	No indication of germ ring.
2.00 P. M., June 5.	Germ ring and embryonic shield.	No indication of germ ring.
7.00 P. M., June 5.	½ over yolk.	Germ ring and shield well developed.
6.30 A. M., July 6.	Blastopore closed. Embryo formed.	½ to ⅔ over yolk.
8.00 A. M., June 7.	Embryo developed with eyes, brain, etc.	⅓ over to closure of blast. Embryo short and completely formed.

Fundulus heteroclitus, female,

×

Stenostomus chrysops, male.

In this cross there is always a fairly large proportion of the eggs fertilized. The per cents in four experiments were as follows:

Experiments	103b	70 per cent.
"	106	40 " "
"	122	30 " "
"	508	58 " "

There is usually a considerable proportion di- and poly-spermic. This amounted to 18 per cent. and 20 per cent. in two experiments in which the count was made. The eggs would develop to the closure of the blastopore with the embryo too short though considerably better formed than in the cross Fundulus heteroclitus and Tautogolabrus adspersus. The embryo in some cases may be two-thirds normal length, with the blastopore remaining a rather large oval or slit. Quite a variety of conditions in blastopore closure obtain here, but do not merit detailed description. The relative rate of development for the normals and hybrids is detailed in Table 7.

TABLE 7.

TIME.	FUNDULUS × FUNDULUS.	FUNDULUS × STENOSTOMUS.
10.50 A. M., July 11.	Fertilization.	Fertilization.
11.37 A. M., July 11.	Begin. 2 cells.	Begin. 2 cells.
11.55 A. M., July 11.	Compl. 2 cells.	Compl. 2 cells.
12.05 P. M., July 11.	Begin. 4 cells.	Begin. 4 cells.
12.35 P. M., July 11.	Compl. 4 cells.	Compl. 4 cells.
12.40 P. M., July 11.	Begin. 8 cells.	Begin. 8 cells.
1.00 P. M., July 11.	Compl. 8 cells.	Compl. 8 cells.
1.05 P. M., July 11.	Begin. 16 cells.	Begin. 16 cells.
11.00 P. M., July 12.	Late cleavage.	Late cleavage.
1.25 P. M., July 12.	Well developed germ ring and shield $\frac{1}{3}$ over.	Some begin. of germ ring.
3.30 P. M., July 12.	$\frac{1}{2}$ over yolk.	$\frac{1}{3}$ over yolk.
7.20 P. M., July 12.	$\frac{2}{3}$ over yolk.	$\frac{1}{2}$ over yolk.
8.00 A. M., July 13.	Blast. closed.	Most nearly closed. Embryos too short.
1.00 P. M., July 13.		No further along.

Fundulus heteroclitus, female,

×

Eupomotis gibbosus, male.

This cross was attempted six times, only three of which were successful. The number of eggs impregnated each time was very small. I do not think this was due to the condition of the milt, because an abundance of apparently good milt was used. The dry method was used and the eggs kept in fresh water.

Experiment	7	Less than 1 per cent.
"	8	" " 1 " "
"	21	" " 1 " "

The eggs were followed to about one-third to one-half over the yolk when they stopped development. An embryonic ring and shield were developed, but the protoplasm did not look normal even in earlier stages of gastrulation showing a relatively opaque appearance compared with normal eggs.

The reciprocal of this cross was not attempted owing to a failure to get ripe eggs of the sunfish.

Fundulus heteroclitus, female.

×

Fundulus diaphanus, male.

Fundulus diaphanus was obtained from a fresh water lake, and was crossed many times in both directions with Fundulus heteroclitus. In the present cross I was never able to get a higher degree of impregnation than 80 per cent. Often I failed altogether and usually there was only an occasional fertilized egg—less than 1 per cent. This may have been due partly to the difficulty of getting enough good milt. In one instance I found about one-half of the eggs polyspermic. The eggs develop along in a normal fashion, going somewhat slower in the later stages, and hatch. I have reared some of the embryos for two weeks and they seemed perfectly active and otherwise normal. The eggs were reared in both fresh and sea water.

Fundulus diaphanus, female,

×

Fundulus heteroclitus, male.

When Fundulus diaphanus is used as the female nearly all of the eggs may be impregnated. Thus:

Experiment	6b	Nearly 100 per cent.
"	13a	" 62 " "
"	18a	" 91 " "

The eggs are practically all normally fertilized and hatched. These I have reared for twenty-two days after hatching.

Fundulus heteroclitus, female,

×

Cynoscion regalis, male.

The eggs of Fundulus are fertilized as perfectly with the sperm of the Squetegue as with its own milt. Thus:

Experiment	513	92 per cent.
"	514	90 " "

Only about 2 per cent. of the eggs are polyspermic. A tabulated outline of the development compared with the normal is as follows:

Table 8.

Time.	Fundulus × Fundulus.	Fundulus × Squeteague.
3.40 p. m., July 17.	Fertilization.	Fertilization.
5.50 p. m., July 17.	2 cells.	2 cells.
6.35 p. m., July 17.	4 cells.	4 cells.
7.25 p. m., July 17.	8 cells.	8 cells.
7.45 p. m., July 17.	Begin. 16 cells.	Begin. 16 cells.
8.10 a. m., July 18.	Late cleavage.	Late cleavage.
12.20 p. m., July 18.	Begin. germ ring.	Begin. germ ring.
7.00 p. m., July 18.	$\frac{2}{3}$ over yolk.	Germ ring; $\frac{1}{3}$ to $\frac{1}{2}$ over.
8.15 a. m., July 19.	Blast. closed; optic vesicles plainly formed.	Blast. closed; optic vesicles poorly formed notocord; somites. Behind normals.
2.15 p. m., July 19.	Optic vesicles and lens; brown parts showing. Hatched.	Optic vesicles showing; behind normals. No further along.

The embryos may continue their development to a stage where the eyes, heart, ear vesicles, tail, etc., are more or less well formed. At this stage they remain alive until about the time that the normals hatch.

None of the embryos are formed even approximately normal. The individual differences are so great that a description of different forms would be of no avail. A brief description of one of the poorer embryos is as follows: The embryo may form a mere mass of cells so far as external appearances go. This embryo becomes pigmented with many pigment cells which are highly branched. It is bilaterally symmetrical in form, but the distribution of the pigment cells only slightly indicates this. In this embryo there was no definitely differentiated heart, but beneath and about one-third the distance back from the anterior end, a mass of cells could be seen regularly pulsating. Just above the heart-mass a vesicle occurred which I take to be the ear. There was no indication of a tail. I repeatedly observed the embryo bend itself from side to side so that there were probably muscle tissues formed on both sides. This particular embryo died nine days after fertilization.

One of the best formed embryos may now be described. Two eyes are formed, although much too small, poorly pigmented, without a lens and set into the anterior surface. Extending out on either side is a large vesicle which is probably an hypertrophied ear vesicle. A pretty well developed tail is shown. Notocord and muscles are developed. A long tubular heart extends across the rather large pericardial sac. The body shows many finely divided pigment cells. These show, in general, a bilateral distribution. Even this embryo is considerably too short. The contractions of the body are vigorous and frequent. The heart beats considerably slower than the normal. This embryo lived until the normals had hatched.

The development of eyes, as in the preceding embryo, is uncommon. There are often pigmented areas which are probably the representatives of this organ, but no definite vesicles or cups. In many of the embryos the anterior end is occupied by enlarged vesicles which is more or less heavily pigmented.

All the embryos are too short, many of them mere short masses of cells without any caudal elongation at all. They are all highly pigmented, the prevailing color being a reddish-brown. These cells are as a rule very finely divided. The dark pigment cells are relatively few in number and are, as a whole, much less finely branched. I have never been able to see any bloodvessels that were carrying blood. In a few instances irregular lakelets, reddish in color, appeared, but I have been unable to detect any corpuscles in them.

In addition to the above crosses it seems worth while to include the other crosses effected. To these much less attention was given so that in a description of them only such points as seem relevant will be given.

Crosses with Gasterosteus bispinosus.

Besides the crosses already described between Gasterosteus bispinosus and Fundulus heteroclitus, the following were attempted:

Gasterosteus bispinosus, female,

×

Apeltes quadracus, male.

In the single attempt to make this cross, only 17 per cent. of the eggs were impregnated. The eggs from a single female were used. It is probable that further attempts with more favorable females would yield a greater per cent. of impregnation. The fertilized eggs were normally impregnated. After the cleavage stages the hybrids fell behind the normals so that while the latter had closed the blastopore, the hybrids had encompassed the yolk about three-fourths of the way. Seven embryos were hatched and were in an apparently normal condition. These were kept alive for four days.

A smaller proportion of the embryos failed to emerge from the membranes. These were helped out but showed the coiled tail so common among fish embryos that seem to have thrived poorly. The hybrids, however, appeared less healthy than a lot of normals that were fertilized at the same time, and kept under the same conditions. These mostly lived three and four days longer. As far as can be judged from this single experiment, it is doubtful whether many of these hybrids, even with the care and proper conditions supplied, could be successfully reared.

Apeltes quadracus, female,

×

Gasterosteus bispinosus, male.

Two tests were made. In one of them 18 per cent. of the eggs were impregnated. The embryos showed the usual slowing in the rate of development after close of cleavage. The development went to the stage of hatching, two emerging but showing little vigor. They died after the second day of emergence. The embryos that failed to emerge, for the most part lived as long as the two which had hatched. The success of this cross is probably the same as that of the reciprocal.

Gasterosteus bispinosus, female,

×

Menidia notata, male.

The eggs of this stickleback are practically all impregnated when placed with Menidia sperm. In the two experiments tried, 100 per cent. and 70 per cent. were fertilized. A small per cent. of these are polyspermic. The development keeps well apace with the normals until toward the closure of the blastopore. The embryo is laid down, the eyes are formed, but the anterior region of body is quite heavy. Pigment forms and the heart is developed. I have never seen fins form in these hybrids. The embryos soon die, owing possibly to the fact that the eggs even normally do not do well in a fingerbowl of water.

Menidia notata, female,

×

Gasterosteus bispinosus, male.

This cross was made but once. All of the eggs were fertilized. The development was followed to the closure of the blastopore. They doubtless developed further since my notes, at this stage, show them to be in a good condition.

Gasterosteus bispinosus, female,

×

Menidia gracilis, male.

In two of the three experiments made with this cross, practically 100 per cent. of the eggs were normally impregnated. The eggs develop at the same rate as the normals until the latter half of gastrulation, when the hybrids fall behind. Most of the eggs form embryos. These are short, with heavy anterior portion. The posterior one-half or one-third of embryo remains quite rudimentary. The anterior enlarged end develops eyes that in the earlier stages are apparently normal. The heart is formed and pulsates. I have kept these embryos alive for five days.

Gasterosteus bispinosus, female,

×

Tautoga onitis, male.

Practically 100 per cent. of the eggs were normally fertilized in the single cross made. The eggs show the usual slowing in development at the close of segmentation. About 50 per cent. of the embryos died at a stage when gastrulation was from one-third to one-half completed. The remainder more or less completely closed the blastopore. The anterior portion of embryo is heavy. No eyes and heart were observed. The embryos died three days after closure of the blastopore.

Gasterosteus bispinosus, female,

×

Tautoglabrus adspersus, male.

Seventy-four per cent. in one experiment and practically 100 per cent. in the other were normally impregnated. The embryos developed more successfully than when Tautoga was used as the male. A large per cent. of the eggs attempted to close the blastopore. The anterior end of embryo was large, eyes and heart were developed but not normally. The embryos lived for five days in this condition.

Menidia notata, female,

×

Tautoga onitis, male.

Eighty per cent. of all the eggs were normally fertilized. The embryos were followed to the closure of the blastopore. The embryos were shorter than normals.

Tautoga onitis, female,

×

Menidia notata, male.

In this cross 60 per cent. of the eggs were impregnated. Some dispermy and polyspermy occurred. There was a heavy mortality at the germ ring stage and subsequently. The ring spread about two-thirds over the yolk in some of them, when owing probably to bad conditions, all died.

Fundulus diaphanus, female,

×

Eupomotis gibbosus, male.

The cross between the fresh water Fundulus and Eupomotis is from the standpoint of impregnation, much more successful than when the egg of Fundulus heteroclitus is used. The percentage of eggs fertilized may be as high as 70 per cent.

Experiment	12	56 per cent.
"	17a	11 " "
"	18b	70 " "
"	22a	23 " "

I have always found a considerable number of imperfect eggs which accounts in a measure for the usual low per cent. of eggs fertilized. A particularly large number occurred in Example 17a. A few of the eggs are polyspermic in each experiment, probably, however, not many more than in the normals, where there may be as many as 5 per cent. polyspermic. The development stops when the protoplasm has spread about one-half over the yolk. Embryonic ring and shield are formed, but very little evidence of embryonic differentiation being shown in the shield. The protoplasm looks granular and opaque instead of clear, as in the normals.

Opsanus tau, female,

×

Fundulus heteroclitus, male.

In the one experiment made, twenty-one out of thirty-seven eggs were found in the 2 and 4-celled stage eight hours and twenty-five minutes after fertilization. A few of the eggs were polyspermic. They were followed to later cleavage.

Opsanus tau, female.

×

Tautogolabrus adspersus, male.

One out of thirteen eggs was impregnated in the single experiment. The rate of cleavage was the same as in the above cross.

Opsanus tau, female,

×

Menidia notata, male.

Thirteen out of seventeen eggs were impregnated. None of the eggs were polyspermic. The cleavage rate was the same as the Opsanus X Fundulus cross listed above.

The reciprocals of the above named three crosses with Opsanus tau eggs were attempted but without success. This was doubtless due to the unripe condition of the Upsanus tau milt, since I was also unsuccessful in obtaining normals.

In addition to the crosses detailed above the following were also effected (See Table 9):

Fundulus heteroclitus ♀ × Apeltes quadracus ♂.
Tautoga onitis ♀ × Tautogolabrus adspersus ♂.
Tautogolabrus adspersus ♀ × Tautoga onitis ♂.
Coregonus clupeiformis ♀ × Argyrosumus artedi ♂.
Argyrosomus artedi ♀ × Coregonus clupeiformis ♂.
Cristivomer namaycush ♀ × Salvelinus fontinalis ♂.

TABLE 9.

CROSS.	FAMILY.	ORDER.	NUMBER OF CROSSES MADE.	PER CENT. OF IMPREGNATION.	REMARKS.
Fundulus heteroclitus ♀ Fundulus diaphanus ♂	Pœciliidæ Pœciliidæ	Haplomi Haplomi	8	0–80	Hatched.
Fundulus diaphanus ♀ Fundulus heteroclitus ♂	Pœciliidæ Pœciliidæ	Haplomi Haplomi	10	62–100	Hatched.
Fundulus heteroclitus ♀ Fundulus majalis ♂	Pœciliidæ Pœciliidæ	Haplomi Haplomi	1	78	Hatched.
Fundulus majalis ♀ Fundulus heteroclitus ♂	Pœciliidæ Pœciliidæ	Haplomi Haplomi	1	90	Up to hatching.
Fundulus heteroclitus ♀ Menidia notata ♂	Pœciliidæ Atherinidæ	Haplomi Acanthopteri	10	70–93	
Menidia notata ♀ Fundulus heteroclitus ♂	Atherinidæ Pœciliidæ	Acanthopteri Haplomi	4	14 to nearly 100	
Fundulus heteroclitus ♀ Menidia gracilis ♂	Pœciliidæ Atherinidæ	Haplomi Acanthopteri	3	About 100	
Fundulus heteroclitus ♀ Gasterosteus bispinosus ♂	Pœciliidæ Gasterosteidæ	Hoplomi Hemibranchii	3	18–86	
Gasterosteus bispinosus ♀ Fundulus heteroclitus ♂	Gasterosteidæ Pœciliidæ	Hemibranchii Haplomi	3	45–100	
Fundulus heteroclitus ♀ Apeltes quadracus ♂	Pœciliidæ Gasterosteidæ	Halpomi Hemibranchii			

Fundulus heteroclitus ♀ Eupomotis gibbosus ♂	Pœciliidæ Centrarchidæ	Haplomi Acanthopteri	6	Less than 1%
Fundulus heteroclitus ♀ Tautogolabrus adspersus ♂	Pœciliidæ Labridæ	Haplomi Acanthopteri	5	17–90
Tautogolabrus adspersus ♀ Fundulus heteroclitus ♂	Labridæ Pœciliidæ	Acanthopteri Haplomi	1	16%
Fundulus heteroclitus ♀ Tautoga onitis ♂	Pœciliidæ Labridæ	Haplomi Acanthopteri	3	40–66⅔
Fundulus heteroclitus ♀ Stenostomus chrysops ♂	Pœciliidæ Sparidæ	Haplomi Acanthopteri	4	30–70
Fundulus heteroclitus ♀ Cynoscion regalis ♂	Pœciliidæ Sciænidæ	Haplomi Acanthopteri	10 Many	20–92 17–92
Fundulus diaphanus ♀ Eupomotis gibbosus ♂	Pœciliidæ Centrarchidæ	Haplomi Acanthopteri	4	23–70
Gasterosteus bispinosus ♀ Apeltes quadracus ♂	Gasterosteidæ Gasterosteidæ	Hemibranchii Hemibranchii	1	17
Apeltes quadracus ♀ Gasterosteus bispinosus ♂	Gasterosteidæ Gasterosteidæ	Hemibranchii Hemibranchii	2	17½
Gasterosteus bispinosus ♀ Tautogolabrus adspersus ♂	Gasterosteidæ Labridæ	Hemibranchii Acanthopteri	2	74–100
Tautoga onitis ♀ Menidia notata ♂	Labridæ Atherinidæ	Acanthopteri Acanthobteri	1	60
Menidia notkta ♀ Tautoga onitis ♂	Atherinidæ Labridæ	Acanthopteri Acanthopteri	1	80 +
Gasterosteus bispinosus ♀ Tautoga onitis ♂	Gasterosteidæ Labridæ	Hemibranchii Acanthopteri	1	100

TABLE 9.—Continued.

Cross.	Family.	Order.	Number of Crosses Made.	Per Cent. of Impregnation.	Remarks.
Gasterosteus bispinosus ♀ Menidia gracilis ♂	Gasterosteidæ Atherinidæ	Hemibranchii Acanthopteri	3	50-100	
Tautoga onitis ♀ Tautogolabrus adspersus ♂	Labridæ Labridæ	Acanthopteri Acanthopteri	2	95	
Tautogolabrus adspersus ♀ Tautoga onitis ♂	Labridæ Labridæ	Acanthopteri Acanthopteri	1	Large per cent.	
Gasterosteus bispinosus ♀ Menidia notata ♂	Gasterosteidæ Atherinidæ	Hemibranchii Acanthopteri	2	70-100	
Menidia notata ♀ Gasterosteus bispinosus ♂	Atherinidæ Gasterosteidæ	Acanthopteri Hemibranchii	1	100	
Opsanus tau ♀ Menidia notata ♂	Batrachoididæ Atherinidæ	Plectognathi Acanthopteri	1	8%	
Opsanus tau ♀ Menidia notata ♂	Batrachoididæ Atherinidæ	Plectognathi Acanthopteri	1	76	
Opsanus tau ♀ Tautogolabrus adspersus ♂	Batrachoididæ Labridæ	Plectognathi Acanthopteri	1	$33\frac{1}{3}$	
Coregonus clupeiformis ♀ Argyrosomus artedi ♂	Salmonidæ Salmonidæ	Isospondyli Isospondyli	2	Large per cent.	Hatched.
Argyrosomus artedi ♀ Coregonus clupeiformis ♂	Salmonidæ Salmonidæ	Isospondyli Isospondyli	2	Large per cent.	Hatched.
Cristivomer namaycush ♀ Savelinus fontinalis ♂	Salmonidæ Salmonidæ	Isospondyli Isospondyli	1	Large per cent.	Hatched and reared to fingerlings.

SUMMARY OF EXPERIMENTS.

INTRODUCTORY.

In the preceding detailed account of the various crosses effected are included combinations between forms of teleosts, ranging from closely related species within the same genus to species belonging to widely separated orders. Their relationships are summarized below, the figures set opposite each indicating the number of different combinations made in each group:[1]

Between different species of same genus	2
" " genera of same family	4
" " families of same order	1
" " orders of same class	17

A number of interesting facts appear from the above table and from a closer inspection of the more detailed Table 9. In all the crosses attempted with the exception of the cross in which Opsanus tau was used as the male, impregnation was possible. The sperm of the single Opsanus tau specimen used was not ripe in the three combinations attempted, so that it is impossible to say whether these crosses are possible.

CHARACTER OF IMPREGNATION.

In many of the crosses the impregnation was wholly normal. In some there was in addition to the normally impregnated eggs, a varying number of dispermic and polyspermic impregnations. Among the abnormally impregnated eggs the dispermic was very much more common than the polyspermic condition. In the dispermic eggs the protoplasmic disc, as is well known, falls at once into four cells. Sections of these conditions show that two male pronuclei fuse with the egg pronucleus; whether additional spermatozoa enter such eggs, but remain functionless so far as early cleavage is concerned, I am not able to say. In the polyspermic eggs the protoplasm falls at once into six or more cells. The cases coming under my observation in which many cells at once appeared, have been rather rare.

PERCENTAGE OF FERTILIZATION.

A striking fact is the large percentage of eggs impregnated. In fully two-thirds of the crosses this ran above 50 per cent., and in many of the combinations it ran above 75 per cent. A glance at Table 9 will show that this is not in any way correlated with the nearness of relationship.

[1] This is represented in more detailed form in Table 9.

The low percentage of impregnation, on the other hand, must be regarded in most cases, I feel sure, as due to unfavorable conditions of the milt, and in some cases to the unripe condition of the eggs. Males that have passed the height of their breeding season, or which may have been less able to endure the conditions of confinement in aquaria usually show a reduced fertilizing power compared to perfectly fresh and ripe individual. The testes were in all the experiments cut out, so that it is quite probable that in many cases imperfect milt was used. I was, furthermore, not able to establish any constant difference in the percentage of impregnations in reciprocals. Allowing for the influence of the condition of the milt in determining the percentage of impregnation, in all cases where a fair trial was made in reciprocal crossing of two species it was approximately as high in one direction as the other. It is interesting to note here that Kammerer '07 using fresh water fishes, found, among the few forms he used, two crosses, Perca fluviatilis x Acerina schraetser and Lucioperca sandra x Perca fluviatilis, in which it was possible to impregnate when the first named in each case was the male, but not if female. It is also impossible to fertilize the eggs of Aspro zingel with the milt from the following nearly related forms: Perca fluviatilis, Lucioperca sandra and Acerina sp?, but was able to fertilize them with the milt from the distantly related form Cottus gobio. It would seem from these experiments that fresh water fishes lend themselves less generally to hybridization than the marine species.

Kammerer's statement that the eggs of Aspro zingel are fertile to the sperm of the distantly related form Cottus gobio when they were immune to the three nearly related forms above indicated, because Cottus had a similar habitat, and had with this also acquired the power to fertilize this species is, of course, a mere fancy. If he had tried to cross this form with other distantly related forms he would probably have found that they, too, would fertilize the eggs regardless of their habitat relationship.

DEVELOPMENT.

In my study of the development of these various hybrids I have not attempted to get a complete morphological picture, nor have I paid much attention to the inheritance aspect. I have regarded development rather from a physiological standpoint. The main points of interest, therefore, have been, first, how generally and within what limits can the sex-products of the various forms of teleosts be grafted upon each other, so to speak, and start development. Second, How far will development proceed in the various combinations, and in what respects are the processes normal and abnormal?

In every combination effected the earlier phases of cleavage are passed through in a perfectly normal manner. The same is true of the later stages of cleavage excepting the rate of development. This will be further considered below. From the late cleavage on, the history of the different hybrids becomes much more varied. In those hybrids resulting from species nearly related—belonging to the same genus or to closely allied genera—most of the embryos may complete their development to the point of hatching, or beyond. Even among these, however, a number variable but much greater than in normal embryos, may show abnormalities along the course of their development, such as occur more abundantly in the hybrids between more distantly related forms. Hybrids between species more distantly related than above indicated, so far as my experiments go, never complete their development to the point of hatching. The stage to which they will go depends again upon the nearness of their relationship. In the more successful of such distant crosses Fundulus-Menidia hybrids, many of the embryos may go far enough to form fairly well developed eyes, ear vesicles, tail, muscles, central nervous system, heart, color patern, fins, etc., but many of these structures in the later stages are variously abnormal. A large proportion of all the embryos, however, fail to reach such advanced stage. From these hybrids we have almost every condition to such as obtains in the hybrids between Fundulus heteroclitus x Tautogolabrus adspersus, where none of the embryos go much beyond the closure of the blastopore, and where it is not possible to speak of the formation of organs. The more characteristic and striking abnormalities appearing beyond the cleavage stage in these various hybrids may be briefly considered.

In the last stages of cleavage and during the earlier phases of germ ring formation it is usually not possible to distinguish the hybrids from the normals excepting in the stage of advancement. In some combinations, such as Fundulus heteroclitus x Tautogolabrus adspersus, etc., one can very commonly see the formation of a rather large clear area under the blastodisc which is filled with a clear fluid. I have followed such eggs and they do not bring their development to as advanced a stage as those eggs of the same lots that do not show this abnormality. They may form a very good embryonic ring and shield and may overlap the yolk for a third of the way and there die. In a few cases the vesicle was observed to be so large as to act as the yolk ball so that the protoplasm attempted to encompass it.

Embryonic shield might form and even lay down the axis of the embryo. These, like the above, soon died. In all hybrid eggs, but particularly those obtained from distantly related species, the period of gastrulation is one of great mortality. The embryos usually enter upon the germ ring and shield stage rather normally and simultaneously, but from this period to the closure of the blastopore the greatest variation in stages obtains. In some of the less successful crosses most of the eggs never succeed in properly closing the blastopore, but come to a standstill so far as this process is concerned at various stages, and continue the rudimentary formation of an embryo in the embryonic shield.

These aborted embryos may in some cases remain alive for days, developing pigment, a rudimentary heart, pericardial cavity, etc.

A very common deformity in the more successful embryos is the failure of the tail to bud out so that the embryos, very generally, are too short. A striking instance of this fact appeared in the hybrids between Savelinus fontinalis, female, and Cristivomor namaycush, male. This cross is quite successful, and the writer has succeeded in rearing 2,300 of them to fingerlings. Among this lot, a very large per cent. were deformed, and in every instance the deformity occurred in the region posterior to the anus. The portion anterior to the anus was normal in every way so far as proportions are concerned. The same is true of the caudal fin. But the region between this and the anus showed all degrees of shortening, the extremes appearing as if the caudal fin were directly set into the body of the fish. The anal fin was often wanting altogether, even in some that had the caudal peduncle otherwise normally developed.[1] This process of the elongation of the caudal end of the embryo seems evidently a difficult one, giving rise to the common abnormalities in this region. In those crosses where a portion of the embryos succeed in laying down the fundamental organs such as the eyes, ears, brain, heart, muscles, etc., promise well to carry their development to completion. In every instance, however, regardless of how normal the organogenetic processes may at first be, they show a very clearly defined abortive influence in a short time. This begins to show itself shortly after the time when the circulation is established in the normal embryo. This fails to develop properly in all these hybrids that fail to complete their de-

[1] A detailed description of these hybrids are reviewed in a separate paper.

velopment. The heart usually differentiates and a pericardial cavity forms which commonly distends to enormous proportions. This has the effect of deforming the heart usually into a much elongated structure. The yolk and the embryo may in some instances differentiate blood vessels, but I have only in one instance observed either the heart or blood vessels handling any blood. The result of this is that the embryo which may up to this period be quite normal in its developmental processes, has its food restricted to what may be directly absorbed from the yolk through other agents than the blood. That the embryo does thus obtain some food is evident from the progressive reduction of the yolk and the increased size, and the long continued life of the embryo.

The eyes in rare cases may be quite normal. From this condition all degrees of abnormalities obtain. The eyes are commonly too small, located too far forward and too low down. Often an eye is developed only on one side. The eye may be rudimentary to the extent of being only a large black pigmented area in the region of the forebrain. A large proportion of the embryo develop no indication of an eye.

The ear may develop as a vesicle which in some cases shows otoliths. Commonly this vesicle becomes must distended, appearing as a prominent projection on either side. The ear less frequently appears than the eye.

The central nervous system may be laid down, the brain even showing some of the primary divisions in the more successful embryos.

The notocord is commonly present. The embryos may develop a varying number of somites, and quite commonly when these are present, some of the cells become contractile so that the whole embryo undergoes movements.

The fins rarely appear, but in some instances the pectoral fins may be much larger than in the normal fish.

If an embryo is laid down at all it rarely occurs that pigment does not develop, both on the yolk and in the body of the embryo. In some cases this may be quite heavily developed, showing accumulations of large and highly branched chromatophores. In the better developed embryos a simple pattern may develop showing varying degrees of bilateral symmetry.

The rate of development of the hybrid egg compared with that of the egg species, was noted in many instances. Comparative tables are given above in the detailed descriptions of the various hybrids.

The earlier cleavage stages in every case was that of the species from which the egg was taken. This is true whether the rate of cleavage from the sperm species is more rapid or slower than that of the egg species. Thus, reference to Table 3, where Fundulus heteroclitus was the egg species and Tautogolabrus adspersus was the male species, the rhythm of cleavage follows exactly that of Fundulus, although that of Tautogolabrus is very much faster. The reciprocal shown in Table 4 shows that the rate again is that of the egg species—Tautogolabrus. This is true all the way through, but attention is called to the hybrids with Opsanus tau, where the cleavage rhythm is relatively so extremely slow. (Page 373.) These facts are in accord with many observations made by others, especially Driesch ('98) on Echinoderms. Newman ('08, '10) obtained the same results in his Fundulus heteroclitus—Fundulus majalis hybrids. Fischel ('06), on the contrary, maintains that the influence of the sperm in some of the Echinoderm hybrids, makes itself felt even in the first cleavage. It is important to note, however, that such influence as he can detect is always to slow the development. This is what I find everywhere, as will appear further on, but I have not been able to detect it during the early cleavage stages. This slowing of the developmental processes is to be looked upon as pathological, a sort of incompatibility of the two germinal substances in such cases as it occurs. If it is permissible, as some authors do, to speak of the rhythm of cleavage as a character of the organism, then all my experiments most clearly show that the rate of earlier cleavage of the embryo is uninfluenced by the sperm, and may be regarded as wholly determined by the egg.

In later cleavage and all subsequent stages, the influence of the strange sperm becomes apparent in all the cases that I have carefully watched. It should be said here that hybrids between the nearly related species were not studied in this particular, but only those between the more distant forms. The influence of the strange sperm was in every case to retard development, usually to a marked degree, regardless of whether the developmental processes in the sperm species was much more rapid or slower than in the egg species. Thus Tautogolabrus adspersus takes only from twenty-four to thirty-six hours to hatch, while Fundulus heteroclitus takes from ten days to fourteen days, the hybrids, using Fundulus as the egg species, are slower in their development than Fundulus itself. The tendency, then, among fish hybrids obtained by combining distantly related species, is to develop slower after their earlier cleavage stages, than the egg species. It is, therefore, interesting to note Newman's result where he found a distinct acceleration in the later cleavage stages and subsequently in the hybrids between Fundulus majalis, female x Fundulus heteroclitus, male.

GENERAL CONSIDERATIONS AND THEORETICAL.

SELECTIVE FERTILIZATION.

In a general consideration of these experiments, perhaps the most striking fact that appears is the uniformity with which it is possible to cross-fertilize the various species of teleosts. The percentage of eggs fertilized is in practically all cases a high one—fifty per cent., and, in the majority of cases, seventy-five per cent. or over. When one reflects upon the reason for one's astonishment at this, he finds it in the fact that we have all, those of us who have given the matter any thought at all, allowed ourselves to grow into the belief that there is a sort of specific affinity or adaptation existing between an egg and the spermatozoön of the same species. This assumption may or may not be true. So far as the writer has been able to determine, there is extant no evidence that this is the case in the animal egg. A possible exception is to be found in the experiments of Dungern ('01), who finds that in the eggs of the starfish there is a substance which is poisonous toward the sperm of the sea urchin, but not vice versa. It is easy to see that under such conditions the spermatozoa of the starfish would be favored.

On the other hand, we have experiments by Buller on all the groups of Echinoderms which seem to show that there exists no specific affinity, chemical or otherwise, between the egg and its own spermatozoön.

The writer is elsewhere publishing a detailed account of his experiments on selective fertilization in fishes. It may be proper, however, to briefly call attention in this connection to a few of the results he obtained. First. The fact above stated, that among these fishes it is possible so uniformly to cross-fertilize the different species lends no support to the "specific adaptation" theory. Second. When a lot of Fundulus heteroclitus eggs are given a chance at a mixture of two sperm, one of which is their own and the other a strange species (Menidia, for instance), the eggs do not necessarily show any preference for their own sperm. In the case above mentioned, for instance, the great majority of the eggs prefer the Menidia sperm to their own. In other combinations the proportion is about equal. In still others the eggs may select more of their own sperm. The factor seems not to be the relationship of the sperm, but its vitality and fertilizing power. Third, Experiments with various egg extracts and the like on the behavior of spermatozoa give no evidence of any attraction of an egg for its own sperm or any toxic influence upon the strange sperm. It seems, therefore, that in the case of these teleosts there is no evidence of any specific adaptation of the egg for its own spermatozoön.

How can we account for these varying degrees of failure in development in these various hybrids? This question is as old as our knowledge of the common infertility of hybrids. Why should an animal or plant hybrid carry its development in a perfectly normal and healthy manner up to the final stage of sex product formation, and yet at this point so commonly fail? To this question we have up to the present time no definite answer whatsoever.

DEGREE OF DEVELOPMENT AND SYSTEMATIC RELATIONSHIP.

In following the development of the various hybrids hereunder discussed there appears one period in the development to which we might ascribe the failure of development, more than any other: this is the defective development of the circulatory system. Development in most crosses proceeds often in a relatively normal manner up to the period of the differentiation of the heart, blood vessels and the blood. In all the hybrids here considered that succeed in forming a circulatory system at all may begin to develop the heart more or less normally, so that it regularly and vigorously pulsates but fails to differentiate the blood and blood vessels. As a result the heart manipulates no normal blood and, as a consequence, the food absorption of the embryo must occur through other channels than the blood. Following this period the embryos invariably begin to lag behind, the organs fail to properly differentiate, resulting in the stunted, sickly-looking, starved hybrid. It would seem that if it were possible in some way to help the hybrids to properly complete this system, development might be carried much further, perhaps up to the point of hatching. But in the case of some hybrids none of the embryos form a heart and a varying percentage of all hybrids fail to develop the heart at all, even though the more successful ones complete development. Furthermore, it often happens that the circulatory system is apparently properly established and the development carried to the point of hatching, or even beyond, but they soon die. Thus while it is undoubtedly true that the establishment of the circulation is a vital stage in the proper progressive development of the embryo and is followed in normal embryos by a period of rapid growth, the question still remains, why does the circulatory system fail to develop properly? Why do we have so many embryos stop their development before the period of heart formation, and why do we have so commonly failures to emerge from egg, or die shortly after, when in the latter the circulation, at least to all appearances, has been normal? If we consider the experiments tabulated in Table 9 from the view point of the correlation between the degree of development and the relationship of the species combined, we see at once that only those species that belong to the same genus, or to very closely related genera, will produce hybrids that develop to the point of hatching. Even within this group a difference in this respect can be observed between species very closely related, and species more distantly related. Thus Fundulus heteroclitus combined in either direction with Fundulus diaphanus will produce a large proportion of free swimming embryos. These two species, although the former is a marine and the latter fresh water, are structurally very closely allied. Fundulus majalis is much less closely related to Fundulus heteroclitus, although belonging to the same genus. When the latter is taken as the female a large proportion of vigorous fry are obtained. The reciprocal has never yielded me embryos that would emerge from the egg, although, with the exception of the yolk bag, normal in appearance. Then the species used belong to separate genera the proportion of embryos that emerge normally is, as a rule, much smaller than in the preceding condition.

All species that are more removed from each other than closely related genera, fail to produce hybrid embryos that will complete development to the point of hatching. Among this latter group of hybrids the stage to which development is carried varies considerably in the different combinations. This, too, can be roughly correlated with the relationship of the species combined, so that two species belonging to distantly related orders like Fundulus heteroclitus x Tautogolabrus adspersus give rise to hybrids that can not go much beyond the closure of the blastopore, while if the same form is crossed with its nearer relative, Menidia notata, development proceeds very much further although stops far from the point of hatching. This will be further taken up below.

We produce, then, among fishes a series of hybrids that range in success from those in which none of the embryos develop very much beyond the "blastopore" stage though intergradations to those in which the embryos hatch normally and grow into adults, probably fertile creatures, and this series is correlated with the systematic relationship existing between the two species crossed.

The work of Guyer ('00) on the spermatogenesis of hybrid pigeons suggests that in the final formation of the sex products, difficulties arise in the synopsis of the male and female chromatim material, resulting in abnormal spermatozoa. Stated in more general terms in the final formation of the sex cell the developmental and hereditary substances from the two parents, fail to work harmoniously, giving rise to abnormal development. It is conceivable that an analogous process takes place in those hybrids that are arrested much earlier in their development. Indeed, the prevailing habit of thinking of developmental and hereditary determinants in terms of units of some sort, suggests at once to our minds some such picture as above indicated. In two nearly related species the developmental mechanisms are so nearly alike that no serious conflicts, so to speak, arise except possibly in the very last stages, namely, the formation of the sex cells. As a result, the development may be completed or all but completed. When, however, two distinctly related species are combined we have to do with two developmental mechanisms that are more divergent, and the conflict develops early in the life of the organism with the consequent modification of development, varying with the relationship. It is difficult to find any appearances in my hybrids that specifically support this view. It would seem that at least occasionally there would appear specific modifications to the influence of the sperm over the egg species. Thus it should be expected that the mode and rate of cleavage, the time and method of gastrulation, etc., should vary in a manner to be in a measure at least due to the specific characteristics of the developmental mechanisms of the sperm species. But this is just what one does not find. The whole process of hybrid development presents the picture of a pathological embryo, such as one sees when they are subjected to an unfavorable condition, such as foul water, insufficient oxygen, unnatural chemical media and the like. It is simply an arrest with subsequent gradual deterioration of the tissues. Thus the monocular condition is likely to result if the optic vesicles fail to form properly and the anterior brain-vesicle becoming pigmented in the cyclopian eye, or only one side develops the vesicle and becomes pigmented. The slender strangulated heart may be accounted for by the abnormally large pericardial cavity which develops, across which it becomes stretched. The large pericardial cavity may be the result of the abnormal method of yolk absorption due to the failure of the blood vessels to differentiate.

I have for three or four years looked upon these phenomena in my own hybrid experiments as a process akin to that which obtains in the transfusion of blood of strange species. The well known results of Landois ('75). Friedenthal ('99) and others bring out the important fact that the hæmolytic power of the bloods of two species varies in intensity with the nearness of relationship of the species. In general two very closely related animals will permit the transfusion of their bloods with no or relatively slight hæmolytic action. As the forms become divergent in relationship the toxic action becomes progressively greater. In a similar manner it has been shown that other tissues than blood act toxically. Among these are spermatozoa. The process in hybridization may be conceived something as follows: When the sperm brings its material into the strange egg in fertilization it brings with it the substance capable of poisoning the egg substance or vice versa. We may suppose that the toxic action does not manifest itself at once because of the relatively small proportion of the sperm substance compared to that of the egg. Consequently early cleavage stages are in all cases passed through in a normal manner. As, however, the nuclear material grows and becomes more generally distributed through the cytoplasmic mass as cleavage proceeds, the toxic action becomes manifest in the retardation of the cleavage and subsequent developmental processes. The intensity of the effect will vary with the degree of toxidity existing between the two species concerned. In the cases of fishes where cross fertilization is so generaluy possible it should be possible to get a measure of this in the faithfulness with which the embryo reproduces the normal developmental processes in the earlier stages, and the stage at which these become arrested.

In the transfusion of bloods we have seen that the toxidity varies rather closely with the systematic relationship of the animals. My experiments so far as they go, show that this same law holds in hybridization, and when taken in connection with what is already well known about the production of so-called "successful" hybrids, I think, may be interpreted as furnishing evidence for this view.

In order to obtain a somewhat more definite idea of the influence of a strange sperm upon the developmental processes, I have made a somewhat careful comparison of the final stages of a series of hybrids all of which had the same species, Fundulus heteroclitus, for the female but different species for the male, these latter varying in their nearness of blood relationship to the egg species. These males fall into four separate groups of two species each. The male species in each group are closely related, but the different groups vary in their relationship to the egg species from that of the same genus to that of most widely separated orders. These groups are as follows:

Group 1	Fundulus heteroclitus	×	Fundulus majalis.
	" "		" diaphanus.
Group 2	" "		Menidia notata.
	" "		Menidia gracilis.
Group 3	" "		Gasterosteus bispinosus.
	" "		Apeltes quadracus.
Group 4	" "		Tautogolabrus adspersus.
	" "		Tautoga onitis.

In group 1, Fundulus majalis and Fundulus diaphanus will hybridize and bring their development to hatching. The same is true of the two species of Menidia in group No. 2. In group No. 3 the two species of sticklebacks will cross and hatch, although I have been able to rear the embryos for only a very short time. The Cunner and Tautog of Group No. 4 will likewise cross and, although many abnormalites occur, some of the embryos will hatch in a normal manner. When, however, these forms are crossed with Fundulus heteroclitus very divergent results are obtained, although in every case most of the eggs are impregnated. In the first group the embryos largely hatch and may be reared. Among the normals may be found various abnormalities, but these are relatively rare. In the remaining groups the embryos never hatch, although in some cases may remain alive in the egg for three or four weeks. But each of these groups go to a characteristic stage of development and show characteristic abnormalities. In all of the last three groups the mortality is great during the period from the formation of the germ ring to the closure of the blastopore.

In group 2 a varying number may go far beyond this stage forming normally the early stages of the eye, ear, heart, notocord, somites, etc. Although the early stages in the formation of these organs may be normal, it soon becomes apparent that the further processes becomes aborted. The blood vessels do not properly differentiate, the pericardial cavity becomes very large and the heart is commonly drawn out to a filamentous form. This continues to beat until the death of the embryo, but does not handle any blood. The eyes do not attain their full size, and may be poorly pigmented. They often are abnormally set so that they occupy the fore-part of the head. This may fuse into a median single eye or may be present on one side only. The ear vesicles often become large and inflated, giving rise to a large rounded prominence on each side. The pigment cells are very finely developed, show a tendency to a pattern and bilateral symmetry, but there is a lack of uniformity in this in the different embryos. The embryos are shortened and may develop abnormally large pectoral fins. It is not necessary to give more than a general description at this place.

Even within this group it is very easy to distinguish between the hybrids in which the Menidia notata is used as the male from those in which the Menidia gracilis is the male. The development of the former is more successful in those that pass the blastopore closure stage, although my experiments show that the mortality is greater at this point. The pigmentation is better developed and the various organs above mentioned are laid down much more normally. As a consequence fewer and less pronounced abnormalities occur. In the Fundulus-Menidia gracilis cross it is not uncommon to have only one eye formed. This may be lateral or may be median. The eyes are commonly set much further anterior so as to occupy the front of the head than in the nearly related cross.

In the crosses of group 3 we obtain quite a different series of hybrid embryos. None of these will develop as far along as those in group 2. There is the usual large mortality preceding and at the blastopore closure stage. The more successful embryos are much shorter, the pigmentation is much less perfect, the black usually predominates, the eyes are never normal, and often altogether wanting, and the life of the embryo is shorter. The heart and pericardial cavity is much the same as in the Menidia hybrids, although I have seen no attempt to develop vessels on the yolk. Their embryos show in every way that the developmental processes have deteriorated much earlier than in the Menidia crosses.

When we come to group 4 we have a still more pronounced abortion of the developmental processes. Many of the embryos close the blastopore after a fashion, but the embryo is always much shortened, usually being a mere streak of protoplasm. These embryos do not lengthen to form a tail, they form no eyes. Occasionally one or two poorly developed ear vesicles show; pigment is irregularly and rather sparingly developed on both the embryo and the yolk. These cells are practically all black with a few small, poorly developed brownish ones. The heart may develop into a protoplasmic pulsating mass showing no definite form. The pericardial cavity is poorly developed or wanting. These embryos may remain alive for a week or ten days, but never as long as the hybrids of the two preceding groups.

We can see from the foregoing that within the narrow limits of the species covered, that the more distantly two species are separated in their blood relationship when crossed, the earlier the developmental processes come to a standstill. The writer, of course, thoroughly appreciates that the foregoing facts are not necessarily evidence in favor of the view taken. He desires merely to emphasize the analogy existing between the conditions of hybridization and the known conditions of blood transfusion and the like. His belief that this analogy is a significant one has been strong enough to lead him into further, more direct experiments along this line. The writer may even be permitted to express a hope of his that it may be possible to control the processes of hybridization in a manner similar to that which has already been brought about in the field of immunity.

SUMMARY.

1. The eggs of any of the species of teleosts tried may be impregnated by the sperm of any other species tried.

2. The number of eggs fertilized is usually great, i. e., 75% or more. This bears no relation to the nearness of relationship of the two species concerned.

3. Normal impregnation is the rule, di- and polyspermy being the exception.

4. Development in its early stages proceeds normally, the deleterious effects of the two strange sex products upon each other showing only at later cleavage or subsequently.

5. The rate of development in the early cleavage stages is always that of the egg species. Any effect of the strange sperm upon the rate of development shows itself by slowing the process regardless of whether the rate of the sperm species is faster or slower than the egg species.

6. A period of great mortality in the developing hybrids is gastrula-

tion. If the heart is formed, although it pumps no blood, the embryo may remain alive for a considerable period, yolk absorption taking place to a varying degree. If the heart handles blood and bloodvessels are differentiated, the embryo is likely to develop to the point of hatching.

7. The numerous abnormalities appearing in the hybrid embryos are due to a deterioration in the developmental processes, resulting probably from the poisonous action of the sex products upon each other.

8. The success of the hybrids, i. e., the stage to which any given hybrid will develop, is correlated with the nearness of relationship of the two species used.

9. The mixing of unrelated sex products is looked upon as analogous to the transfusion of unrelated bloods, the more distantly related the two species concerned the greater their toxidity.

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The Fauna of a Solution Pond.

By Will Scott.

INTRODUCTION.

In 1909 I gave an account of the plankton of the subterranean stream in the caves of Indiana University's cave farm. Among other things it was found that the plankton is composed of epigean forms and is derived from ponds in such sink-holes as have an opening above their lowest points. A study of the fauna of the ponds furnishing the cave plankton became desirable.

[1]Contribution from the Zoölogical Laboratory of Indiana University No. 119.

Ponds of this kind form a fresh water "unit of environment" typical for an area covering a part of twenty counties of southern Indiana, a strip of Kentucky and a part of Tennessee. Instead, however, of making a general study of the faunæ of many of these ponds, a typical pond one-half mile northeast of the campus of Indiana University has been studied intensively. Its fauna has been determined, its physical factors and environment analyzed, and the processes at work determined in part, at least.

Observations on this pond extend from October, 1908, to June, 1909, and from September, 1909, to September, 1910, with occasional visits from September, 1910, to May, 1911. It was visited weekly or more often during all but the summer months. No observations were made during the summer of 1909, but the pond was visited monthly during the summer of 1910 (June 15, July 16, August 12).

Many other ponds have been examined, but detailed data concerning them have not been collected. The observations on these have been incorporated in this paper when they made clear facts that could not be determined from this pond alone.

Aside from presenting a picture of the conditions in this pond, I hope the data collected may furnish a basis for comparison with the larger bodies of fresh water (glacial lakes and rivers), so many of which have been under observation in recent years.

THE POND.

The form of the pond may be seen by reference to the map, No. 1. It is oval in shape and has a maximum length of 70 feet and width of 57 feet. Its greatest depth is 46 inches, but this is attained only during the heavy rains of spring. The south, east and north slopes are quite gentle, but the west slope is so abrupt that within one foot of the shore, on the north end of the west side, a depth is attained which is only six inches less than the greatest depth of the pond. The bottom is covered with plant debris mixed with a little fine clay derived from the wash from the slope above the pond. This silt is small in quantity, the slope being slight, the area drained small, and a narrow zone of grass surrounding the pond.

Location.—The location of this pond may be determined by examining the Bloomington Quadrangle of the United States Topographical Survey. It is 940 feet above sea level and about 150 feet above the floor of the valleys one mile distant. It is about 16 feet below the crest of an old monadnock, probably a remnant of the tertiary peneplain and near the level of the pleistocene peneplain which forms the "skyline" in this region.

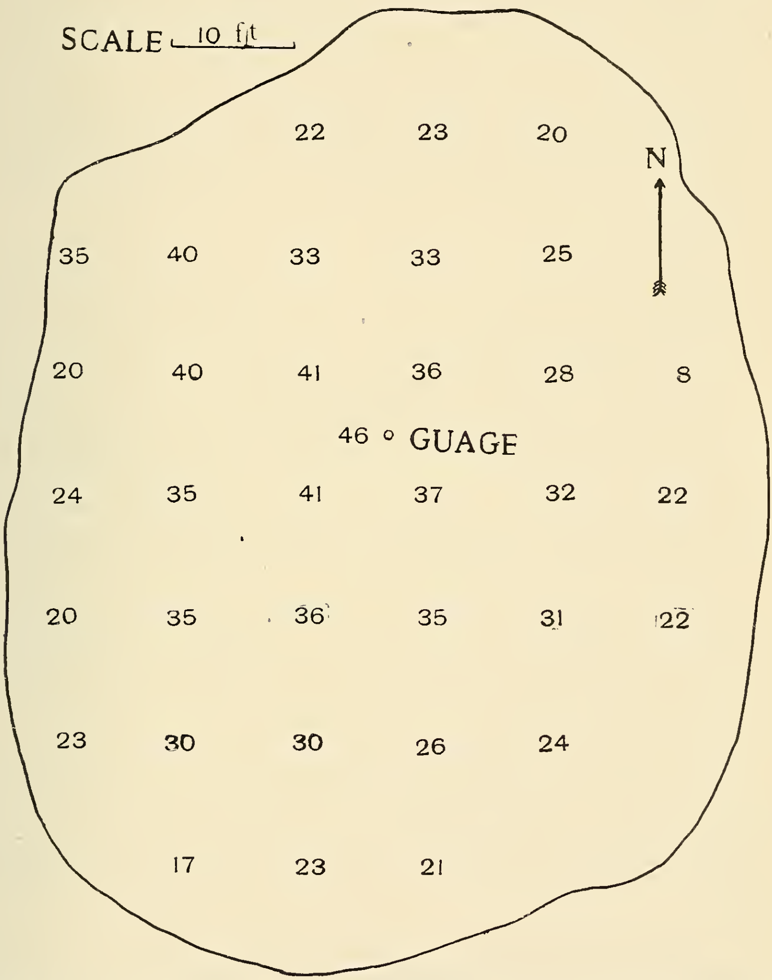

Fig. 1. Map of Hill Pond, showing depth in inches at 10-ft. intervals when at the overflow point.

The pleistocene peneplain is very much dissected in this locality. This particular monadnock is completely isolated, valleys having cut into its sides from three directions, viz., south, west and north. The valley to the north empties into Griffey Creek, a part of the drainage system of the West Fork of White River. The valleys to the west and south empty into Clear Creek, a part of the drainage system of the East Fork of White River.

No similar pond is nearer than two miles. The nearest perennial water is in springs .33, .56 and .66 miles distant, and 100. 146 and 165 feet respectively below the level of the pond. The accompanying profiles indicate these slopes graphically. Fig. II. These statements indicate the isolation of the pond.

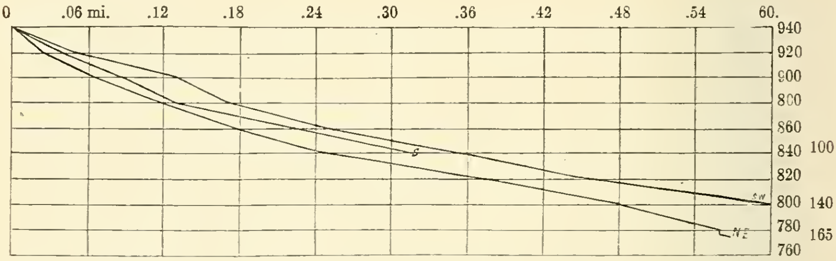

Fig. 2. Profiles of valleys leading away from hill on which pond is located, from pond to closest permanent water in each valley.

The pond is formed by solution in the Mitchell limestone which caps the hill to a depth of 50 feet and overlies the Bedford limestone, both being formations in the Mississippian series. The details of the formation of this pond are not different from those of any other of this region, consequently a general discussion will probably be more enlightening.

The development of sinkholes is coincident with that of subterranean drainage systems. Both depend upon two conditions: First, the presence of soluble rock, usually limestone; second, the movement of the solvent (meteoric water, containing as it always does, carbonic acid), through the rock.

In order to have a movement of meteoric water through the rock, it is necessary to have an outlet below the general level of the country. This is secured by the invasion of surface drainage. A study of the topography of a limestone region shows that in general the sinkholes are formed on the periphery of the valleys.

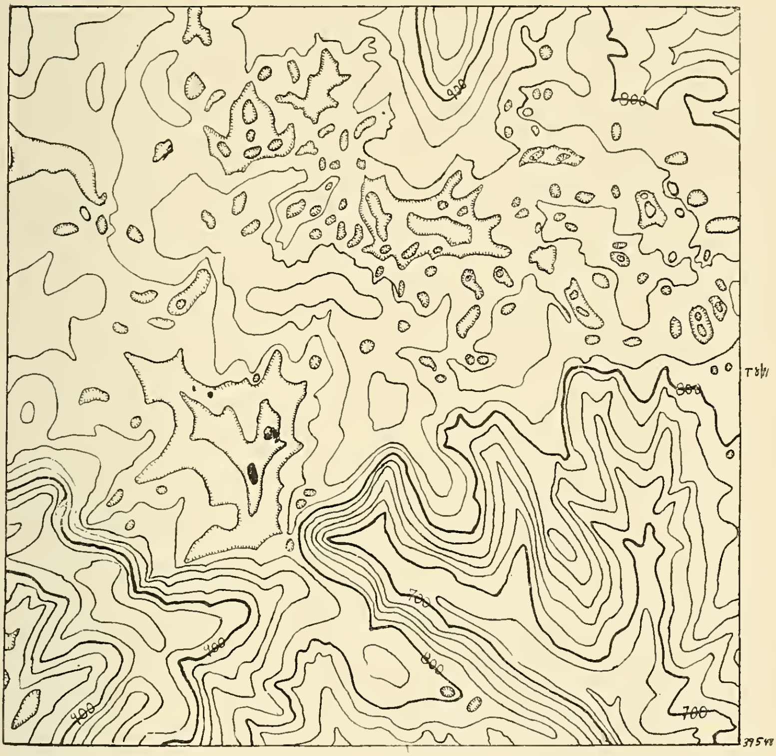

Fig. 3. Map showing the formation of sink holes on the periphery of a valley.

The accompanying map (Fig. III) beautifully illustrates this point. It is based on data from the Bloomington quadrangle of the United States Topographic Survey. A deep gorge from the southeast cuts well into the old peneplain, thus tapping the water table. The water on plain around the periphery of this valley "sinks" into the limestone and comes to the surface near the bottom of the gorge.

In the area under discussion, the Ohio river and its tributaries supply the surface drainage. Although any sort of limestone may develop sinkholes, the Mitchell is the sinkhole and cave-forming limestone par excellence. Its qualities in relation to cave formation have been discussed by Green ('08). He summarizes them as follows:

"The Mitchell limestone, otherwise known as the St. Louis, barren, or cavernous limestone, is a bluish or grayish, hard, compact, even-grained stone, generally having a conchoidal fracture. It is so compact as to make it rather impervious. Intercalated layers of blue-gray shale are frequent. Large concretions of chert are characteristic of certain horizons. When the stone weathers, these masses of chert do not dissolve, but break into more or less angular fragments which strew the ground over the Mitchell area. In Indiana the formation is also characterized by the common presence of a genus of corals known as Lithostrotion or Lonsdaleia. In some places, such as western Monroe or southern Crawford County, there is a typical white oölite found near the top of the formation.

"Analysis shows the Mitchell to be a very pure calcium carbonate, and at Mitchell, Lawrence County, from which place the formation received its name, it is extensively quarried for making lime and cement.[2]

"The Mitchell limestone has long been known as the Cavernous limestone. Both the Wyandotte Cave of Indiana and the Mammoth Cave of Kentucky occur in its strata. In three counties in the vicinity of Mammoth Cave, over five hundred caves are known to exist. These facts lead us to investigate the general adaptability of this limestone to cave formation.

"The reasons of this adaptability are numerous. Besides the bedding planes, two sets of vertical joint-planes exist, one set having a general east and west direction and the other a north and south direction. Vertical joint-planes are probably more numerous in this than any other of the Mississippian limestones. Owing to the fact that the Mitchell is rather impervious and often of a lithographic nature, the down flowing water is forced to follow the joint and bedding planes. The underlying Salem limestone contains joint-planes but is porous enough to become thoroughly saturated instead of confining the water to joint-planes."

The presence of joint-planes, its impermeability and its solubility, are the qualities of the Mitchell limestone which make it favorable to the development of caves and sinkholes. It is obvious that if a stone is impermeable and has joint-planes, the water will trickle down through these joints instead of being absorbed by the rock. If the rock is soluble and the

[2] In the southern part of the State it reaches a thickness of 350 to 400 feet; in the central part of its area, that is, in Lawrence and Monroe counties, the thickness is from 150 to 250 feet, and from here gradually thins toward the north."

water contains carbonic acid gas in solution, as all meteoric water does, cavities will be formed in it.

The regions in which sinkholes occur were originally covered with deciduous forests and as a result the surface was covered with decaying vegetable matter. It is well known that this condition reduces the surface *run off* and allows more water to sink into the ground. Shaler ('91) has also shown that this decaying humus produces a large amount of carbonic dioxide, so that the water, passing through it, is always saturated with this acid. From these facts, it is probable that the formation of caves and sinkholes formerly occurred more rapidly than at present.

What causes a sinkhole to develop at a particular point is somewhat conjectural. Something occurs which increases the rate of solution at a particular point. There may be a place in the stone which is more soluble than the surrounding rock. It has been suggested that fault-lines may be the initial cause of at least some of them. There is a fault near the mouth of Shawnee cave in the Mitchell limestone but no line of sinkholes has developed along it.

It is quite possible that the tap roots of some of the walnuts, oaks and similar trees of the original forests may have determined the location of some of these depressions. These tap roots undoubtedly reached bed rock in many places. When they decayed they left a funnel shaped opening in the soil, filled with their own decaying stems. This funnel would conduct meteoric water immediately to bed rock and charge it with CO^2 as it did so.

Cummings ('05, page 87) explains this formation as follows:

"Where two joints intersect, the enlargement is apt to be greatest, giving origin to funnels, narrowing gradually downward, and showing in a beautiful way the formation of sinkholes, which are only such funnels of solution grown large."

Whatever may initiate this process, after connection is once established with a subterranean system, the processes of weathering, erosion, etc., enlarge the funnel in every direction. The funnel is really a valley whose source or upper end is the perimeter of the cone and whose mouth or outlet is the opening in the center. The sides of a young sinkhole are usually very steep and its area limited, while those of an older one are more gentle, with a much larger area. At any stage in the development of a sinkhole, its outlet may become obstructed. The result is the formation of a pond. If a young sinkhole is obstructed, a small and relatively deep pond results. The obstruction of an old sinkhole results in the formation of a shallow pond of considerable area.

Destruction.—The ponds are no sooner formed than their destruction begins by means of those factors which destroy all such topographic forms. Few of them overflow, anl these only for a short time. Plant deposition and the deposition of silt are the two principal factors operating for their destruction. A pond formed in a young sinkhole which is located at or near the summit of a hill, i. e., near the level of an old peneplain, does not have as much silt washed into it as does a pond formed in an older sinkhole or one that is located on the lower slope of a hill. Plants are relatively a much greater factor in the destruction of the former than in the latter.

Our pond belongs to the first class. It has some clay deposited in it. but plant debris forms the major part of its sediment. The rate of its destruction is known approximately for a period of 24 years. In 1887, it was about eight or nine feet in depth ("deep enough to swim a horse"). It is now slightly less than four feet, a difference of four feet. or one-fifth foot deposition per year. So far as I know, this is the only case where the rate of plant deposition is reducible to even approximate figures.

The water is usually clear. A scum of iron oxide was found on the surface April 1, 1910. On August 12, 1910, the water had a dark purplish tinge, due to the decay of organic matter. The only time the pond was seen to be muddy was after the rain of July 14. On this date it was quite opaque and of a yellowish tinge, from the suspended silt. Silt is carried into the pond only after very heavy rains, for reasons previously stated.

METHODS.

For collecting insects, insect larvæ, algæ, amphibian larvæ, etc., ordinary insect nets and dip nets made of bobbinet and scrim, were used. A very useful net for collecting micro-organisms, when quantitative work is not demanded, is a sampling net, manufactured by the Simplex Net Company, Ithaca, New York. It is made of bolting cloth No. 20, is three inches in diameter, twelve inches long. and is operated by being thrown out into the water and then drawn in. The ring is quite heavy so that it will sink if properly handled. The depth at which the net moves can then be regulated by the rate at which it is drawn through the water.

The only difficulty experienced in operating this net was that the ring carried the open end under at once, thus catching enough air in the net to float it. To obviate this difficulty, a 25x80 mm. glass shell partially filled with water was fastened to the apex of the net by means of a cork stopper. This carried the net under at once, and when the catch was made. the cork was loosened and the collection dropped into the bottle.

For quantitative work, on such plankton as was present, the following variation of the pumping method was used: The whole apparatus had to be light enough to be portable. Some difficulty was experienced in getting a satisfactory pump. The pump used is known in the trade as the Barnes hydroject pump, manufactured by Barnes Mfg. Co., Mansfield, Ohio. It has a brass cylinder and throws one-fourth liter per stroke. Its general appearance is shown in Fig 4. To this was attached a net of bolting silk (Dufour No. 20) and a detachable bucket. (Windows covered with wire cloth. 200 meshes to the inch.) A three-quarter inch hose (inside measurement) was used. The end was closed with a cork and an opening made in the side of the hose just above the cork, so that the water from a given level might be secured with greater accuracy. The end of the hose was fastened to a float, so that the collection could be taken from any depth desired. By means of a rope and pulley, this float could be placed at any point in the pond.

Material was killed in a 4% solution of formalin. All organisms were counted in every collection except two. In investigating a small area, I believe that greater accuracy is secured by filtering a small amount of water and counting all the oragnisms than by filtering a large amount and counting a fraction of it. The amount counted in either case must be large enough to include samples of all the organisms present.

The source of error in the first case is the uneven distribution of organisms at a given level. In the second case, the error is due to the difficulty of thoroughly mixing organisms having a different specific gravity.

The soundings were taken when the pond was covered with ice. The ice was ruled at ten-foot intervals, holes bored at the intersections, depth measured through these openings and entered on the map of the pond. A guage was set December 21, 1909. From the readings of the gauge, the depth at any point at any time could be determined.

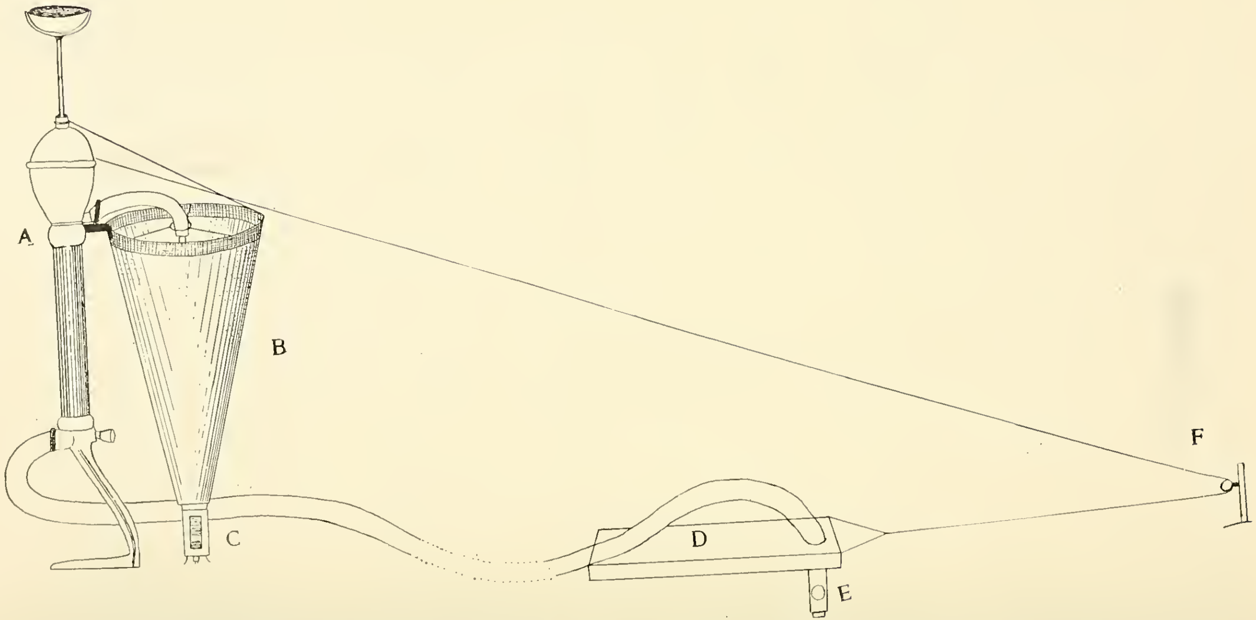

Fig. 4. Plankton outfit used on pond. A, pump; B, net of bolting silk; C, detachable bucket; D, float; E, intake; F, tackle for placing float.

The data concerning elevation were taken in part from the United States relief map of the Bloomington quadrangle, and in part from averages of the barometric readings. The bench mark established by the survey on the university campus rendered exact correlation possible.

The following annoted list of species gives a fairly complete picture of the life in this pond. The list of flagellates and desmids is not exhaustive. The diatoms were not identified because of the inadequacy of accessible literature. However, it may be stated that the diatom flora consists of bottom inhabiting forms.

PROTOZOA.

Rhizopoda—

Difflugia globulosa Dujardin.

This was the most common protozoan in the pond. It was found at all seasons but was more common in 1910 than in 1909. It is reduced in numbers during the winter but when the temperature begins to rise in the spring, this species begins to increase in numbers. In 1910 this increase was very regular from March to August. The Difflugia in the quantitative plankton collections of that year belonged for the most part to this species. In these collections the number per 100 liters varied from 28 on February 8 to 39,780 on August 12.

Difflugia oblonga Ehrenberg.

This variable species was a common form in 1909 but not so plentiful in 1910.

Difflugia acuminata Ehrenberg.

Not common.

Difflugia urceolata Carter.

Common in the winter of 1909-'10. Greatly outnumbered by D. globulosa in the spring and summer. In plankton material killed in formalin, I found a typical individual of *urceolata* with the mouth of its shell closely appressed to that of a specimen of D. Globulosa. Whether this was a case of fission, an animal building a new shell or an accident, I am unable to state. I am inclined to the belief that the animal was dividing. The rounded shell was slightly smaller than the spined one. If this be true, the distinction between the two forms is of course not specific.

Difflugia corona Wallick.

Observed occasionally.

Difflugia lobastoma Leidy.

Rare.

Many variations in the nature and form of the test have been observed. The studies of Penard ('02), Averintzev ('06) and others have resulted in more than forty species being referred to this genus. The many variations observed in the Difflugia in this limited habitat make evident the value of studies on the effect of age and environment upon the form of the test. Such studies would certainly define the species more clearly than they are at present. The difficulties of such experiments are obvious.

Lesquerensia spiralis Schlumberger.

Rare.

Pontigulasia compressa Carter.

Nov. 9, 1909.

Arcella vulgaris Ehrenberg.

This species was very common on the bottom and in the vegetable debris during the year 1909 but it was very much reduced in numbers the next year. In the collections taken with the pump from Jan. 5 to Aug. 12, it occurred but once.

Centropyxis aculeata Stein.

Occurred rarely. Taken Jan. 5, 1909.

Actinophrys sol. Ehrenberg.

It was not found until May 28, 1910, when the water temperature was 20° C. It was quite common on that date and during the following month.

Flagellata—

Euglena viridis Ehrenberg.

Always present, but reaching its maximum development in Aug., '10, when 27,560 per 100 liters of water were taken by filtering with No. 20 bolting silk. This filter undoubtedly allows some to pass through.

Phacus pleuronectes Müller.

Phacus pyrum Ehrenberg.

Both species were present among the filamentous algæ at all seasons but never in great quantity. The former was much the more common. On account of their association with the algæ they were always more plentiful in the margins of the pond.

Peridinium tabulatum Ehrenberg.

A form that was referred to this species was observed in some material brought into the laboratory Jan. 18, 1910. This material consisted of debris and water. It was kept in a clean glass jar covered with glass.

Ordinarily this species develops in swarms but it never occurred in quantity in the pond.

Trachelomonas annata Ehrenberg.

Obtained Jan. 18 and Feb. 2 by the same method as *Peridinium,* already described.

Ciliata—

Halteris sp.

Common among algæ at south end of pond, Apr., 1910.

Vorticella.

This genus occurred sporadically during the warmer months. Specific identification was not made every time it was observed.

It was present as late as Nov. 25, 1909, and reappeared in May. The most common form was referred to *V. microstomata Ehrenberg. V. campanula Ehrenberg* was present in large quantities Oct. 26, 1910, when the water temperature was 13.6° C.

Epistylus sp.

A ciliate belonging to this well marked genus was taken March 11, attached to the edge of the thorax (usually near the posterior angle) of an aquatic beetle. It is not referable to any species to whose description I have access. The zooids, when completely expanded, are 1/5 mm. long by 1/12 mm. wide. The stems branch dichotomously and are segmented at the base of each branch. The planes of successive branchings are usually at right angles to each other. The branches are from 30 to 40 μ long and from 20 to 30 μ wide. From this method of branching the colony tends to form a spherical sector of increasing size. The outer surface of this sphere is formed by the zooids, which when contracted in a well developed colony, touch each other forming a continuous surface. The cell walls are fairly firm and a limited surface is exposed. Some water is probably retained among the stalks below the zooids. This seems to enable them to prevent desiccation in a degree. The following observations support this inference: A well developed colony attached to a bit of the thorax of a beetle was left on a slide under a cover glass at 4:20 p. m., room temperature about 70°. The water under the cover soon evaporated. At 7:50 a. m. the following day, the slide was examined. The outlines of the contracted zooids were still discernible. The colony was removed to tap water in a stentor dish. At noon, about 20% had revived and were actively feeding. The amount of drying to which they had been subjected seems to be near the limit for the species. They do not recover if completely desiccated. The relation of this to distribution will be noted subsequently.

PLATYHELMINTHES.

Trematoda—

Diplodiscus sp.[3]

Young trematodes belonging to this genus were taken from the alimentary tract of the larvæ of Rana catesbiana Shaw during Feb., '11.

They were free in the intestine of the amphibian larvæ. The contents of the digestive tract of the worm seemed to be derived from the surrounding medium, i. e., the food material in the intestine of the "tadpole." Sexually mature individuals were taken from larvæ of the same frog about one month later (Mar. 20, '11). I have been unable thus far to determine the invertebrate host of this trematode in this pond. The most numerous mollusc is Luccinea retusa Lea. But many dissections have failed to reveal trematode infection.

The following intermediate stages taken with the plankton catches in the open water have been noted. One cercaria on each of the following dates: May 5, '09; Jan. 11, '10; Apr. 15, '10.

A ciliated larva was taken May 28, '10. The only evidence that these are the developmental stages of Diplodiscus is that Diplodiscus is the only trematode known from this pond.

TROCHELMINTHES.

Ten rotifers were identified from the pond. Others were observed occasionally but were not identified. Their rare occurrence, and the fact that the methods used in the preservation of the material were not especially adapted to rotifers, often rendered exact identification impossible.

Of the ten rotifers, three, *Anuræa aculatea* Ehrenberg; *Hydatina senta* Ehrenberg, and *Monostyla lunaris* Ehrenberg, occurred in quantity in the open water of the pond. The first was common in 1908, the other two in 1910. The other five were never common.

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[3]Identified by Prof. H. B. Ward,

Anuræa aculatea Ehrenberg.

Found Nov. 25, 1908, two days after the rain which ended the drouth of that year. It was quite numerous that fall and was present the following year until December, but not in such numbers. It was absent entirely in the collections of 1910.

Cathypna luna Ehrenberg.

May 15, 1910. Not common.

Diurella tenuior Gosse.

Spring 1907. Rare.

Pedalion mirum Hudson.

Present in considerable numbers during May and June, 1909.

Rotifera tardus Ehrenberg.

April 15, 1911.

Anuræa cochlearis Gosse.

In quantitative collection of April 14, 1910. One specimen; spines well developed.

Hydatina senta Ehrenberg.

Appeared rarely in spring of 1910. First observed April 14. It did not develop in any quantity until July. On July 15 there were 1,560 per 100 liters of water. Aug. 12, this had increased to 1,625.

Monostyla lunaris Ehrenberg.

Appeared April 19, 1910. On that date there were 88 per 100 liters. It reached its maximum development in July with 1,463 per 100 liters.

Monostyla cornuta Ehrenberg.

Aug. 15, 1910. This form may have been counted with preceding but partial re-examination of material did not show this to be true.

Diglema forcepata Ehrenberg.

Occasionally from Feb. 4 to Aug. 15, 1910.

ANNELIDA.

Oligochæta—

Limnodrilus sp.

An oligochæte worm belonging to the family Tubificidæ was referred to this genus. Its complete anatomy has not yet been worked out. It occurs in great numbers among the roots and about the root stalks of Typha. In this pond, this is its exclusive habitat. The alimentary tracts of these worms are always filled with decaying vegetable matter. They are ravenously eaten by Amblystoma larvæ and Diemyctylus. These two facts probably account for their occurrence in this limited habitat.

CRUSTACEA.

Arthropoda—

Daphnia pulex DeGeer.

Occurred twice, in March and April, 1909, and in May, June and July, 1910. Its maximum occurrence was on June 15, 1910, when there were 80 per hundred liters of water. In towing collections, often but a single specimen was taken.

Simocephalus vetellus Mueller.

The most conspicuous crustacean of the pond. It is numerous at all seasons among the plants and plant remains. It is rarely taken in the open water of the central part of the pond. Adults were taken two days after the rain which terminated the drouth in 1908. It was found that in cultures it takes from 10 to 12 days for adults to develop. From these facts, it appears that this crustacean was able to survive the drouth as an adult. To do this, it must have worked its way down through the vegetable debris to the water level. It is present at all periods of the year, producing a maximum of 25 young in a brood. It makes a slight diurnal vertical migration. This is difficult to demonstrate quantitatively because of its habitat. If the surface of the water be "skimmed" with a fine meshed net during the day, very few if any individuals are taken. However, many individuals are taken by this operation at any hour of the night during the summer months.

Alona quadrangularis Müller.

Appeared in March, 1910. Taken with young in brood chambers. Never more than 120 per hundred liters until May 28, when 696 per hundred were taken. It varied during June, July and August from 500 to 780 per hundred liters, the maximum occurring on Aug. 12. Eggs were present in brood chambers in a large per cent. of them from April till August of this year.

Cypridopsis vidua Brady.

Appeared as soon as the pond began to fill with water in Nov., 1908. During the following winter and spring it was one of the most conspicuous forms. No attempt was made to estimate its numbers, but a small quantity of water dipped from any part of the pond during this period always contained them. They could be seen feeding at any time on vegetable debris, Typha stems and algæ.

During the spring of 1909 the number began to decrease, and in the autumn they disappeared. They were never observed in 1910, although the pond was examined for them many times. This fact has an important bearing upon the general problem of distribution, as will be pointed out later.

Cypris virens Jurine.

This form has been present at all times but never developed in great quantity. Its greenish color and the fact that it is more closely confined to the substratum than *Cypridopsis vidua*, render it less conspicuous.

Cyclops serrulatus Fischer.

Taken March 17, 1910, with eggs. Numerous in the shallower parts of the pond during the latter part of the month.

Cyclops bicuspidatus Claus.

The typical form was present during the spring of 1910 but did not occur in great numbers.

Most females taken were carrying egg sacks. During July and August as noted in the discussion of the plankton, this species occurred in great numbers, the maximum being on August 12, when 704,600 per 100 liters were present. However, the individuals were smaller and the stylets shorter and relatively thicker than in the spring forms.

Pearse ('05) reports this species as occurring in the spring in Nebraska. In the Illinois River, it is reported as a winter form, Kofoid ('03). In Lake Michigan it is a summer form, Forbes ('82). In Wisconsin lakes it is active in the cooler parts of the year and passes the summer in a gelatinous cocoon. The seasonal distribution in different habitats of this variable form offers an enticing problem.

Cyclops phaleratus Koch.

Taken during March, 1910. Numerous April 15, 1911. Found among Typha and near the edge of the pond.

TARDIGRADA.

Macrobiotus.

A form which was referred to this genus was taken in the spring of 1910. They occurred in quantity on April 23, and for about one month thereafter, in the gelatinous matrix around the eggs of the mollusc *Succinea retusa Lea.* They did not occur in egg masses recently laid. As the eggs develop, the matrix gradually disintegrates and a large number of minute flagellates develops in the matrix during this process of disintegration. This, in part, accounts for the presence of the Tardigrada, for they were feeding on the flagellates, the disintegrating matrix or both.

On May 15, one was taken containing 10 eggs which almost filled the specimen. June 15, one was taken with 11 eggs. Others taken at this time also contained eggs.

None was taken after June 15. Those taken on this date were captured with a silk net in open water.

Hexapoda—

Notonecta sp.

This backswimmer emigrated from the pond when it dried up, if it had been present previously. It was not observed during the spring of 1909, but since that time it has been abundant.

Limnobates lineata sp.

Frequent near the margin of the pond.

Hygrothechus sp.

This water strider was first observed March 7, 1909. They appear soon after the ice melts and remain until the freezing weather. Adults hibernate. They are primarily the scavengers of the surface, yet the rapidity with which they perform their work makes observation difficult, as the following example indicates: On Mar. 24, 1910, an ichneumon fly accidentally fell into the water. Instantly it was punctured by three of these water-striders. In spite of its larger size and powerful struggle, the ichneumon was soon reduced to practically an empty shell.

Cnemidotus 12-punctatus Say.

Always present on plant stems and debris. Noted by Blatchley as more common in northern part of State than in southern. Hibernates.

Cnemidotus muticus Leclerc.

Occurs with preceding species. Rather more common. Hibernates.

Hydrocanthus iricolor Say.

Present in considerable numbers throughout the year.

Laccophilus maculosus Say.

Laccophilus fasciatus Aube.

Both species present in about equal numbers. Hibernate

Hydrovatus pustulatus Melsh.

About the southern limit of its range. Present throughout the year but not numerous.

Coptotomus interrogatus Fabricius.

One of the common beetles in the pond. Could be taken in numbers at any season.

Graphoderes liberus Say.

Blatchley notes concerning this beetle: "Putnam and Lawrence counties, frequent in woodland ponds." In this pond I have taken but one specimen and have seen no other. This was taken June 6, 1910. It is quite probable that it had just immigrated.

Dineutes assimilis Aube.

Present from April to October in characteristic groups on the surface of the pond.

Tropisternus mixtus Leclerc.

The most common beetle in the pond. Could be seen beneath the ice in winter.

Berosus peregrinus Herbst.

Not common.

Of the four families of beetles found in this pond, the Gyrinidæ are confined to the surface, the Haliplidæ occur at the bottom "crawling" over the plant stems and sticks, while the Dytiscidæ and Hydrophylidæ occupy the intervening space as well as surface and bottom. The surface supports one species, the bottom two, while eight species are more generally distributed. The Dytiscidæ are represented by six species, the Hydrophilidæ by two. The Dytiscidæ are much stronger swimmers and more voracious feeders than the Hydrophilidæ, which facts may account for their more successful occupancy of the pond.

Hetærina americana Fabricius.

Taken flying over pond Aug. 12, 1910.

Lestes congener Hagen.

Taken Sept. 1, 1910. On that date they were numerous over pond.

Ischnura verticalis Say.

Emerging June 18.

Anax junius Drury.

A single specimen Aug. 12.

Sympetrum vicinum Hagen.

Two specimens taken June 18.

Libellula pulchella Drury.

June 18, July 16, Aug. 12. Emerged from nymphs in aquaria during June and July. Nymphs of this form were the most numerous of the group.

Libellula lydia Drury.

Flying over pond Aug. 12.

Corethra.

Corethra larvæ either had never been in this pond before 1909, or had been exterminated by the drying up of the pond in the autumn of 1908. The latter proposition seems to be the correct one.

As stated previously, no collections were taken during the summer of 1909. In the autumn when observations were resumed, corethra larvæ were present in enormous numbers. Their numbers have not appreciably decreased since. The reappearance of the larvæ may be accounted for either (1) by eggs having lain dormant during the dry period and winter, and then hatching as the temperature increased the following spring, or (2) adult imagoes may have migrated to the pond during the spring and summer of 1909. I think that the first proposition is untenable because on May 25, 1910, larvæ 3 mm. long were present that had been hatched from the eggs of that year. It is not likely that larvæ of that size could have escaped observation the previous spring. If the species was re-introduced into the pond by the imago, it necessitated a migration of over a mile. Wind doubtless influences these flying forms, so that their migration was partially passive.

Chironomus sp.

Larvæ occurred rarely.

MOLLUSCA.

Gastropoda—

Succinea retusa Lea.

The most common mollusc of the pond. Eggs laid in April, May and June. Hatched in about 15 days. This period probably varies with temperature. At 12°-14° C., eggs laid April 8 hatched April 23.

Tebennophorus dorsalis Binney.

This slug is common in Indiana. However, only a single specimen was taken in the pond, Oct. 16, 1910, in the debris at the bottom. (It seems to have been recently introduced.)

Ancyclus tardus Say.

Not uncommon. This shell is reported by Call ('99) to be common in the Wabash, Ohio and Maumee rivers. In all references that I have been able to find, it is recorded from streams. But most expeditions that were for the special purpose of collecting molluscs, were made along streams. The forms from the land-locked pools have been collected more incidentally. These facts, together with the small size of the species, account for the oft repeated statement of its distribution.

Vertebrata—

AMPHIBIA.

Amblystoma jeffersonianum Green.

The adult of this form has not been taken in the pond, but is known from the ravine to the north. Egg masses, referred to this species, were present March 17, 1910. One mass contained 19 eggs and another 29. March 24, 1911, a mass was observed containing 24 unhatched larvæ. Diameter of outer envelope, 13 mm. Diameter of total mass, 60 mm. Length of larvæ, 13 mm. Fastened to grass 13 cm. below surface.

Diemyctylus viridescens Rafinesque.

Common. Six taken in an area about one foot square in February, 1911. Its habits have been worked out in detail by Gage ('91) and Jordan ('93).

Hyla pickeringii Holbrook.

Three. Numerous. Appeared March 24, 1910. Eggs in May.

Rana catesbiana Shaw.

Common. Nine specimens taken during May, 1910. Egg-laying period, June and July. Recently laid eggs as late as July 15. Reduction in level kills many eggs.

AVES.

Anas discors Linnæus.

A duck was flushed from the pond April 21, 1909. Identification was made while the bird was on the wing. It circled three times, coming quite near. The identification is probably correct. This bird has the greatest range of any individual organism found on the pond. The A. O. U. check list, 1910, gives its range as: North America in general. but chiefly the Eastern Province north to Alaska and south to West Indies and northern South America; breeds from northern United States northward.

It is altogether probable that other water birds visit this pond. I have seen various species of ducks and sand pipers on similar ponds in this region. On the water works reservoir. a small artificial lake about three miles distant, ducks, loons, grebes, etc., may be seen almost any time during their migration period. McAtee ('05) lists 44 water birds from this region, 20 of which he marks as regular migrants.

Agelaius phœniceus Linnæus.

Red winged blackbirds were first seen on the pond May 5. 1909. Two pairs nested during the summer of 1909 on the south part of the pond. The nests were attached to the Typha stems over the water. Three pairs nested near the same place in the pond in 1910.

Many other birds were seen near the pond or perched on the Typha stems. The most common of these were: Turtle Dove, *Zenaiduro macroura L.;* Quail. *Colinus virginianus L.;* Tree sparrow, *Spizella monticola Gmelin;* Fox sparrow, *Passerella iliaca Merrem;* Field sparrow, *Spizella pusilla Wilson;* Junco. *Junco hyemalis L.*

FLORA.

Algæ—

Closterium dianæ Ehrenberg.

April 1, 1910. Common among filamentous algæ.

Cosmarium botrytis Menegh.

Common, spring 1910.

C. tetraophthalmum Kuetzing.

Rare.

Docidium crenulatum Rabenhorst.

This and other species of this genus occurred sparingly in most collections.

Spirogyra majuscula Kuetzing.

During the winter of 1909-10. This alga developed in considerable quantity in the southern part of the pond.

Zygnema stetlum Agardh.

A few filaments observed Nov. 23, 1909, Jan. 9, 1910. Never observed in fruit.

Oedogonium undulatum Brebisson.

The most abundant alga in the pond. It is present throughout the year. It was observed fruiting sexually on Nov. 16, 1909, and April 13, 1910. After the sexual season in the spring the plants decline in vigor. There are enormous numbers of oospores present in the water at this time.

Chaetophora pisiformis Roth.

Common at all seasons on stems.

Typha latifolia L.

This is the most conspicuous plant in the pond. It covered the shallower two-thirds of the pond in 1908 and has since increased to about three-fourths of the total area. It is from this plant that most of the vegetable debris on the bottom of the pond is derived.

In 1910 shoots appeared from the stolons Mar. 24. Seeds began germinating April 8. flowers were formed in June and seeds were ripe early in September.

The seeds which fall in the water are usually blown to the lee side of the pond where they collect in dense masses. This results in very weak seedlings during germination. A slight reduction of level is fatal at this period. Besides this, the margin where these seeds germinate is already occupied by parent plants. From these facts, it is evident that the seeds of Typha are very inefficient in increasing the number of plants in a pond where it is already established. The increase is derived chiefly from buds from the stolons. The seeds, while ill adapted to this function, are very efficient in securing the introduction of the species into ponds unoccupied by it. On a spike 150 mm. long, I have estimated the number of seeds to be 27,000. How far they may be carried by wind is conjectural, and on that account this efficiency can not be reduced to figures. The chances of introduction of any wind-blown seed is inverse to the distance from the center of distribution, but the proportion is unknown. Certainly it is greater in the direction of the prevailing winds than in any other. It may be observed that if the seeds were distributed evenly over a circle whose radius is one mile (the distance to the nearest pond) a seed from each spike would have approximately five chances in six of hitting a pond of that size (70 ft. in diameter) placed anywhere in this circle.

Table No. 1.

Table Showing the Number per 100 Liters of the more strictly Plankton organisms present January–August, 1910.

SPECIES.	Date.											
	1/25/10	2/8/10	2/26/10	3/17/10	3/31/10	4/14/10	4/28/10	5/14/10	5/28/10	6/15/10	7/16/10	8/12/10
Euglena acus Ehr. (?)	140	2,860	3,712	18,240	25,680	132	....	....	....	....	....	....
Euglena viridis Ehr	280	2,552	7,880	4,184	548	17,616	1,316	488	736	848	300	27,560
Phacus	12	4	....	....	36	16	....	32	56	40	2,792	....
Difflugia	72	28	36	76	840	1,548	368	2,244	3,960	7,440	17,772	39,780
Polyarthra	....	....	....	....	....	....	246	5,612	27,564	7,468	184	....
Monostyla	....	....	....	....	....	....	88	240	604	368	1,467	1,040
Hydatina	....	....	....	....	....	....	....	16	....	....	6,240	6,500
Nauplii	....	....	....	68	236	408	20	52	....	....	2,136	80,860
Cyclops	....	....	....	4	28	52	8	4	8	80	1,048	70,460
Daphnia pulex	....	....	....	....	....	....	....	16	12	80	60	....
Alona quadrangularis	....	....	....	....	....	8	24	120	696	500	600	780

Alisma Plantago aquatica L.

Occurs sparsely at the margin of the pond.

Covers the bottom between the Typha stalks on the north and east sides of the pond.

These three phanerogams occur in the pond. Near the margin of the pond occur Bidens and Carex, whose principal relation to it is that they cause the deposition of much of the silt before it reaches the pond.

PLANKTON.

The accompanying table records the observations on the more abundant and more strictly plankton organisms in the pond from Jan. 25 to Aug. 12, 1910. The most apparent fact is the dearth of organisms in the open water during the extremely low temperature of January and February, Euglena virides Ehr., and Euglena acus Ehr. being the most abundant. A few rotifers were observed during the winter, but no marked development of this class was observed until the latter part of April. Polyarthra reached its maximum on May 28, and Monostyla in August. Hydatina is strictly a summer form.

Wesenberg-Lund ('08, p. 255) states: "Rhizopoda are, so far as my experience goes, of quite secondary importance in the pond plankton." This pond certainly differs from those of Denmark, for the development of Difflugia is constant and fairly regular from February to August, when 297,800 per cu. m. were present. Actinophrys was very common near the margins during May.

There are two pulses of cyclops. A very slight one in April and an enormous one in August. It is possible that some of the cyclops were able to avoid the intake of the collecting apparatus. This of course would make the members in the table too low. In April the cyclops were quite evident in the shallow water near the shore. However, it was difficult to apply quantitative methods to this region. During the August pulse, none was seen near the shore. This may have been due to the fact, noted elsewhere, that they were smaller than *C. bicuspidatus* usually is.

ECOLOGICAL RELATIONS.

In the ecology of any association of organisms, two complicated problems or sets of problems present themselves. These are (1) how was each of these organisms introduced, (2) what factors condition their continuance? Without presuming to give a final answer to these questions, I shall present such facts as bear on the distribution and interrelations of the organisms of this pond.

On the basis of methods of dispersal, these organisms fall into two groups, active migrants and passive migrants. The active migrants include the vertebrates and insects, which are limited, for the most part, to the American continent, while the passive migrants include all the other forms which are practically cosmopolitan in their distribution. To discuss the distribution of the active migrants would involve a consideration of their relationships and phylogeny which is not within the province of this paper.

Of the passive migrants, the crustacea, rotifera, protozoa, and most of the algæ are known from both Europe and America. Some of the forms have a much wider distribution. Difflugia, for example, is recorded by Bütschli from all the continents except Africa (where it doubtless exists). Recently Edmonson ('10) has reported *Difflugia pyriformis* from Tahiti. The presence of this form on a recently formed isle, geologically speaking, 4,000 miles from a mainland, certainly makes probable its worldwide distribution.

The cosmopolitan distribution of the passive migrants can, I think, be explained by an analysis of the agencies by which they are carried. Of these agencies, the principal ones are birds, beetles and wind.

Of the birds, only the water birds need be considered as the relation of land birds to aquatic organisms is accidental.

De Guerne ('88) established that water birds do carry a great variety of small aquatic organisms. In examining the fresh water fauna of the Azores, he discovered that the micro-organisms belonged to species found in France. This suggested water birds as a distributing agency. He took a wild duck (Anas boschas L.) and made cultures from the dried particles of slime from its bill, feathers and feet. From these cultures he obtained protozoa, rotifera, nematoda, algæ, cladocera, ostracoda, bryozoa and insect larvæ.

Zacharias ('88) points out the fæces of these birds as an additional source of micro-organisms. I have seen but two water frequenting birds on this pond, but it is occasionally visited, in all probability, by those in whose migration path it lies. Of the twenty-two water birds which are *regular* migrants or residents (including the blue winged teal, the kildeer

TABLE NO. –.

Showing the Water Birds Which Are Common in the Vicinity of the Pond at Some Time During the Year.

Species.	Regions Over Which They Are Distributed.							
	U. S. A.	Canada.	Mexico.	Central America.	South America.	West Indies.	Europe.	Greenland.
1. Horned grebe, Colymbus auritus Linn	+	+	+	+	....	+	+	....
2. Pied billed grebe, Podilymbus podiceps Linn	+	+	+	+	+	+	....	....
3. Loon, Gavia imber Brünnich	+	+	....	....	....	....	....	....
4. American merganser, Merganser americanus Cass	+	+	+	+	....	+	....	....
5. Hooded Merganser, Lophodytes cucullatus Linn	+	+	+	....	....	+	+	....
6. Mallard, Anas platyrhynchos	+	+	+	+	....	+	....	....
7. Green winged teal, Nettion carolinense Gmelin	+	+	+	+	....	+	....	....
8. Blue winged teal, Querquedula discors Linn	+	+	+	+	....	+	+	+
9. Shoveller, Spatula clypeata Linn	+	+	+	+	....	+	....	....
10. Pintail, Dafila acuta Linn	+	+	+	+	....	+	+	....
11. Wood duck, Aix sponsa Linn	+	+	....	....	....	....	....	....
12. Canvas-back, Marila vallisneria Wils	+	+	+	+	....	+	....	....
13. Lesser scaup-duck, Marila affinis Eyt	+	+	+	+	....	+	+	+
14. American golden eye clangula, Clangula americana Bonap.	+	+	+	....	....	+	+	+
15. Canada goose, Branta canadensis Linn	+	+	+	....	....	+	....	....
16. American bittern, Botaurus lentiginosus Montag	+	+	....	....	....	+	+	....
17. Great blue heron, Ardea herodias Linn	+	+	+	+	+	+	....	....
18. Wilson's snipe, Gallinago delicata Ord	+	+	+	+	+	+	+	....
19. Pectoral sandpiper, Picobia maculata Viell	+	+	+	+	+	+	+	+
20. Solitary sandpiper, Totanus solitaris Wils	+	+	+	+	+	+	+	+
21. Spotted sandpiper, Actitis macularia Linn	+	+	+	+	+	+	+	....
22. Killdeer, Œgialitis vocifera Linn	+	+	+	+	+	+	+	....
Total	22	22	19	16	7	20	11	5

and the twenty marked by McAtee ('05) as common), all are found in the United States and Canada, 19 reach Mexico, 16 Central America, 7 South America east of the Andes, 20 the West Indies, 5 Greenland and 11 are reported from Europe. (See Table No. 2.)

Of the 24 other water birds listed as rare or occasional from this region, three reach Chili and one Greenland. The range of no individual bird is as great as that of its species, but many of the water birds are gregarious at some season, so that the organisms which they carry would soon be distributed over their entire range. This does not necessarily mean that these organisms would develop over the entire area.

The following examples show how the area may be connected with the rest of the globe. Besides the four, indicated in the table as occurring more or less regularly in Europe, others appear accidentally (Headley, '95). The Turnstone (Headley l. c.) migrates from Greenland across Europe to Australia. Holbœll's Grebe (Colymbus holboelli Reinh) is distributed over North America, Greenland, Eastern Siberia, south to Japan, thus connecting America and Asia. These forms all breed inland so that they are related strictly to the fresh water fauna. The list may, of course, be extended almost indefinitely. Marine birds, such as the albatross have a much wider range but they rarely come inland.

Birds are the chief agencies in the distribution of crustacea (cladocera, copepoda), whose eggs are too large to be wind-blown. The reduction in the number of water birds which has taken place in the last half century certainly has reduced the chances of a crustacean reaching a pond at the period suitable to its development. In the larger bodies of water this relation is not so evident nor so patent because they are much more static.

Insects migrate very short distances compared with birds. However they do carry organisms from one pond to another in a limited locality. The aquatic beetles and some Hemiptera are the most efficient agencies because the imagoes spend most of their life in the water where algæ and protozoa become attached to them. Occasionally, however, they leave the water, as is attested by the fact that they collect around a light at some distance from their habitat.

In this pond I have often noted beetles with vorticellæ and other ciliates attached. The attachment of stalked ciliates to beetles is mentioned by Stein ('54) and others. Migula ('88) having found a single beetle associated with algæ in a pool 30 cm. in diameter near the summit of Biskiden mountains, concluded that the beetle had carried the algæ. Later he examined six beetles belonging to three species, from five different habitats and found attached to them twenty-three species of algæ.

These ciliates and algæ, however, were attached to beetles *in the water.* When the beetles leave the water these attached organisms are suddenly transferred from an aquatic to an ærial environment. This new environment differs from the old one in temperature and humidity. How long these organisms can resist these changed conditions and how long the beetles stay out of water are facts that must be known before the role of insects in the distribution of attached organisms can be accurately determined. The fact that aquatic beetles fly at night reduces the harmful effect of evaporation. Experiments are planned to solve these problems.

In the notes on *Epistylis*, I have indicated that that species of this genus can remain out of water for some time without fatal results. The colony referred to remained on a slide under cover in a room with low relative humidity for more than fifteen hours without it being fatal to all of the zooids. While a colony of this species attached to the thorax of a beetle making a nocturnal migratory flight would not have the protection against evaporation of the two glass plates, this would be compensated in some degree by the more humid and cooler night air.

That wind is responsible for the distribution of many protozoa and rotifers is a fact which is familiar to any one who has ever made a hay infusion. The presence of these organisms and of tardigrada in the pond, is probably due to wind distribution. Just how far an organism can be transported by wind depends upon the size and specific gravity of its spores, eggs or cysts, and upon its power to resist drying, extreme temperature, etc. These facts are, in a large number of cases, unknown.

Cysts of Euglena are common in almost every culture, but it does not follow that this is the form in which they are wind-blown. Assuming a constant specific gravity, it is certain that the buoyancy of a cyst increases as the reciprocal of its diameter. As an adaptation to this law, many organisms form extremely minute spores.

It is rendered very probable by Calkins ('07) that in *Amœba proteus* very minute spores are formed. From his figures I have determined the diameter of the tertiary nuclei (which with a bit of cytoplasm are presumed to form the spore), to be 1 μ or less. Comparing these spore nuclei in Calkins ('07), Fig. 14, with the amœba figured in his earlier papers.

Calkins ('04), it certainly becomes evident that there is an efficient adaptation to wind distribution.

Attention may be called to the analogous transportation of volcanic dust which has been known to drift round the world. Volcanic dust has a higher specific gravity than that of protoplasm but, on the other hand, it is blown to a very high altitude, while organic spores usually start from the surface.

The exact nature of the spore while in the air must be known before its distribution by wind can be even approximated by direct methods.

Distribution.—Of the complicated set of factors that condition the existence of these organisms, only four can be discussed at this time. These are level, light, temperature and food relations. The chemical composition of the water and its variations have not been determined. The determination of the dissolved oxygen, carbon dioxide and ammonia will probably yield valuable results in a comparative study of several ponds.

Level.—The factor that affects the organisms in this pond most vitally is the extreme changes in level. The level varies from zero to 46 inches above the lowest point. So far as ascertained, its level has been reduced to zero (i. e., it has dried up) but once in its history and that was in the late summer and early autumn of '08. It did not overflow until the following March. From March, '09 to August, '09, the lowest observed level was 35½ inches. The summer of '08 was the dryest in 13 years (local records are not available before 1896). That of '09 was rather wet, 4.75 inches of rain falling on July 14. For these two rather extreme years, the minima have been 35.5 and 0; or to put it another way, the level has decreased 25% and 100% from the maximum. This point will be discussed more fully later. As the destructive forces gradually elevate the bottom of the pond, it is probable that in future the pond will go dry more often. Level is determined by precipitation and evaporation. The extreme variability of these factors in this pond and similar ones in this region is indicated by the weather records of the local station and those from Indianapolis. Records of sunshine, wind velocity and relative humidity are not available for any station nearer than Indianapolis (56 miles distant).

In the accompanying table I have compiled all the climatological data available for this locality.

TABLE 3. CLIMATOLOGICAL DATA.

BLOOMINGTON, MONROE COUNTY, IND.—Elevation, 800 feet.

Precipitation.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1887	2.50	6.35	3.35	3.48	1.25	......	......	......	......	......	......	......	......
1888	1.18	......	......	......	......	......	......	......	......	......	......	......	......
1895	......	......	......	......	......	......	......	......	......	......	......	3.47	......
1896	1.06	2.60	2.10	T.	5.12	3.52	7.78	7.49	4.16	1.35	4.36	0.90	40.44
1897	3.17	3.35	10.63	6.02	2.37	6.27	2.62	0.59	0.72	1.33	7.42	3.24	47.73
1898	6.42	2.15	10.30	1.88	3.94	3.03	2.69	4.43	7.28	4.00	3.13	2.90	52.15
1899	4.06	4.10	4.71	1.96	4.18	2.34	1.60	1.20	0.48	2.91	3.58	3.68	34.80
1900	2.25	3.55	3.35	1.14	4.79	5.73	3.54	1.64	2.54	4.00	3.30	2.05	37.88
1901	2.15	2.15	5.42	3.81	1.00	4.49	0.77	2.63	0.99	4.03	0.95	4.75	33.14
1902	0.90	2.50	2.89	2.86	4.40	5.02	4.19	4.64	4.06	3.40	4.51	5.28	44.65
1903	4.44	6.05	4.75	4.23	2.22	2.55	3.90	5.46	1.50	2.70	2.11	2.91	42.77
1904	5.50	4.05	9.86	2.80	3.67	4.44	2.20	1.60	4.84	1.30	1.00	6.10	47.36
1905	3.05	2.82	3.30	4.81	5.55	2.67	4.27	8.05	2.15	7.35	1.73	3.30	49.05
1906	4.61	2.05	9.31	2.15	2.45	3.39	2.30	7.38	2.99	1.08	4.90	4.94	47.55
1907	9.74	0.74	6.48	3.11	3.98	3.79	4.35	3.12	2.52	4.80	4.20	4.10	50.93
1908	1.50	7.85	5.26	5.51	8.91	1.93	1.81	2.06	0.83	0.29	2.65	2.05	40.65
Means	3.57	3.59	5.84	3.13	3.84	3.78	3.23	3.87	2.70	2.96	3.37	3.55	43.43

	Length of record.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Average number of days with 0.01 inch or more precipitation	13	8	7	10	8	10	10	7	7	6	5	7	8	93
Maximum temperature	13	70	68	84	87	93	97	103	98	100	88	78	72	103
Minimum temperature	13	-11	-20	0	22	29	42	51	50	28	22	5	-10	-20
Mean temperature	13	30.7	29.3	43.3	51.0	64.5	71.9	76.6	75.1	68.6	57.4	44.2	33.2	53.8

TABLE 3—Continued.

INDIANAPOLIS, IND.

	Length of record.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Relative humidity (percentage)...	21	79	77	73	66	67	68	65	67	68	68	73	77	71
Sunshine (percentage).............	12	41	47	40	51	53	62	68	63	66	61	52	40	54
Average hourly wind velocity (in miles)........................	12	11.7	11.5	12.1	11.3	9.9	8.9	8.2	7.4	8.3	9.4	10.4	11.5	10.0

During the period Nov.—June, the level of the pond is not rapidly reduced. September and October are on the average the dryest months of the year. July and August are the hottest. It is during this period (July—Oct.) that the level is reduced most rapidly and the stress on the organisms is most acute. In this period occurs the minimum precipitation, lowest relative humidity and smallest number of rainy days (i. e., .01 inch *or more* precipitation), the maximum temperature and the greatest sunshine percentage. All of these factors tend to reduce the level of ponds by evaporation. The lower wind velocity tends to reduce the evaporation to a slight degree.

The amount of stress produced by a reduction of the level varies in different years. In thirteen years of precipitation records for Bloomington, the minimum for four months, July—October, was in 1908. The maximum occurred in 1896. In 1908 the amount of precipitation for the four months was 4.99 inches. In 1896 the maximum was 20.78 inches. The average for the entire thirteen years for these months was 12.66 inches. To state it another way: the minimum for this period was 39+% of the average and 23.5+% of the maximum. That is, between four and five times as much rain fell during this period of one year as fell during the same period of another year. This irregularity, more than any other factor, prevents the fauna of this pond and all *small* solution ponds from becoming even relatively static. In the larger ponds the effect is less acute.

The drying up of the pond in '08 killed all the amphibian larvæ, the corethra larvæ and caused the emigration of some of the aquatic beetles.

(I am informed that *Dytiscus marginalis* Linn was formerly obtained from this pond in quantity for laboratory dissection material.) I have never taken a specimen from the pond. What other forms may have been eliminated by this "drying up," I do not know, because I began to study it at this period.

Not only were the conditions during this period of low level very different from those preceding it, but the conditions after the dry period were also very different.

When the pond began to fill with water in November, '08, the decaying amphibian larvæ and other organic matter developed conditions favorable to the production of an enormous number of flagellates. This decaying organic debris and possibly the flagellates furnished an immense amount of food for some of the crustacea, especially *Cypridopsis vidua* Brady. The algæ are eaten by both the amphibian larvæ and *Simocephalus vetellus.* The elimination of the former greatly increased the food material of the latter.

The dragon fly nymphs and possibly Corethra larvæ feed on on both of these crustaceans. Thus the conditions at this period furnished the crustacea an enormous food supply and few enemies. The result was a very great development of crustacea. Especially was this true of *Crypridopsis vidua* Brady. Since the winter of 1908, conditions which I have not been able to determine have resulted in the entire elimination of this form. It is evident that variations in the level may result in the elimination of a species or its abnormal development.

Temperature.—The seasonal development of different forms as indicated in the list and table, is probably due directly or indirectly to changes in temperature. The temperature in the water of the pond varies from 27.8° C to 0 at the surface (ice) and to 1.3° C at the bottom.

Except for the first few weeks the temperatures were taken with a centigrade thermometer graded to 1/5ths. The winter of 1908-1909 was fairly open. Ice formed December 2, lasting until January 20. Ice was present the latter part of February but there was none after March 3. The maximum thickness of ice for this year was 2.5 inches. The winter of 1909-1910 was very severe for this latitude. Ice formed December 7 and lasted until March 2 and had a maximum thickness of 9 inches on January 11. During the first winter, the temperature of the water a few inches under the ice, varied but slightly from the greatest density temperature.

The long period of low temperature during the winter of '09-'10 reduced the temperature of the water appreciably.

In order to determine the difference in temperature between the water immediately under the ice and that near the bottom, the following simple apparatus was used. A large mouthed bottle with a glass stopper was laced firmly to a stick of convenient length and a cord was tied to the stopper. The bottle was lowered to the level desired and the stopper removed by means of the cord. The bottle was thus filled with water of approximately the same temperature as that surrounding it. The thermometer was then lowered into the bottle and the whole apparatus was made fast to the ice for about an hour. The bottle with the thermometer in it was then raised and the reading made. The error resulting from this manipulation was very slight. The following readings were recorded:

Jan. 11, 3 inches under ice, 2.2; near bottom, 3.1 C.

Feb. 1, near surface, .8; near bottom, 2.8 C.

Feb. 26, lower surface of ice, .1; near bottom, 1.3 C.

These data indicate that after the pond is sealed with ice, the temperature of the water gradually approaches zero. This lowering of the temperature and the establishment of a difference between the upper and lower strata is due to surface radiation.

Another condition which reduces the temperature of the water is the partial melting of the ice. As has been stated, the pond has Typha growing in it near the edge. The Typha stems project through the ice all winter. When the ice begins to melt, the heat absorbed by these stems, melts holes through the ice around them. The pond then has a zone of openings at its periphery. On January 18, 1910, the ice was partially melted; five inches of solid ice remained. This was covered with four inches of water. The holes had formed around the Typha stems. A stiff wind was blowing from the west. The result was a movement of water from west to east above the ice, and from east to west below the ice. As the temperature of the water above was approximately that of melting ice, its circulation below the ice must have lowered the temperature of the water. (See Fig. V.)

Another factor which may have a slight influence on the temperature of the lower strata, is the decay of organic matter which covers the bottom. This, of course, goes on very slowly at low temperatures.

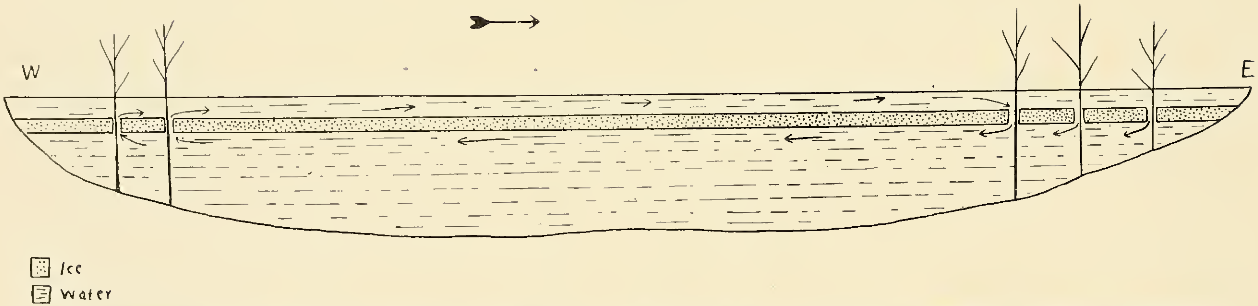

FIG. V. Showing the movement of water caused by wind when the ice is partially melted. Arrows in water indicate direction of water current. Arrow above indicates the direction of wind. Typha stems are indicated diagrammatically near the periphery.

The observed maximum (27.8° C.) is probably not the real maximum as no continuous series of summer temperatures was taken, and the diurnal change in temperature was very great during the variable periods of autumn and spring. The greatest observed variation for twenty-four hours being 10° C. on Oct. 11-12.

Temperature above 4° C. does not seem to affect the forms which are found in the pond throughout the year, i. e., beetles, Corethra larvæ, amphibian larvæ, etc. Below this temperature, however, their activity is decreased and below 2° C. they are quite passive. For some time after the ice formed in the winter of 1909-1910, the Corethra larvæ could be found in all parts of the pond. Amphibian larvæ came to the surface when the ice was cut, and the beetles could be seen crawling on the Typha stems beneath the ice. On Jan. 11, 1910, the upper layers of water (three inches under the ice) had a temperature of 2.2° C. The lower layer (24 inches under the ice) was 3.1° C. There were few Corethra larvæ in the upper layer and these were quite inactive. Near the bottom of the pond in the deepest part, they were present in great numbers and were much more active than those in the upper layers. Larvæ from either region became more active when the temperature was raised. Many dead larvæ were found just below the ice. It may be concluded then that a temperature below 4° C. reduces the activity of Corethra larvæ. At 2° they become quite passive and temperature lower than 2° may prove fatal.

Amphibian larvæ were active and could be captured in quantity during December and most of January. On Feb. 1, 1910, the central, Typha free part of the pond was carefully dredged for amphibian larvæ but none were captured. Holes were then cut in the ice nearer the margin of the pond. Two larvæ were captured ten feet from the north end. These were in the debris among the Typha stems. They were rarely captured until the ice disappeared in March. On March 3, the ice had disappeared and the larvæ were much in evidence. The temperature just under the ice on Feb. 1 was .8° C. and near the bottom was 2.8.

It seems that the formation of ice on the surface does not cause a quiescent stage in amphibian larvæ but a temperature of about 2° C. does reduce their activity. It may be, in both these cases, that it is the *continued* low temperature that causes these stages of inactivity. However, in the winter of 1908-1909, the water was not above 4° C. from Dec. 2 to Jan. 27 and no period of inactivity was observed in these forms.

TABLE 4. MONTHLY AVERAGE OF TEMPERATURE FOR THE PERIOD NOV., 1909—APRIL, 1910.

Month.	Temperature near Surface.	Temperature near Bottom.
November......	13.25° C.	
December......	4.° C.	
January.........	3.4° C.	
February.......	.3...................................	2.05° C.
March..........	6.7° C.	
April............	15.4° C.	

Temperature records are not complete for warmer months, but those taken indicate that the temperature of the water approximates closely the average diurnal temperature of the air, which data are given in detail on page 425.

Most of the aquatic beetles of this pond hibernate as imagoes. After the freezing weather comes they are to be found in the plant remains that cover the bottom of the pond. Their movements are very slow, and usually consist in crawling rather than swimming. On Jan. 13, 1909, ½ inch ice, 5 inches snow, water temperature 2.2° C., a beetle (*Tropisternus mixtus* Lec.) was watched for 20 minutes. It was crawling on a Typha stem and during this time left it but once, swimming away a few inches and then returning.

It may be argued that this quiescent state of the larger forms in the pond is due to the reduction in the amount of oxygen rather than to low temperature. I have not determined the amount of oxygen present during different seasons of the year. However, the filamentous algæ which are present all winter certainly produce some oxygen and it is highly probable that the Typha stems allow some gaseous interchange to take place between the air above the ice and the water below it. I have made the following simple experiment with beetles (5 species), Corethra larvæ, and Notonecta. Two glass jars which were exactly alike, were filled with water to the same level. An equal amount of Typha stems was placed in each. In one, the stems were completely submerged, while in the other one, the end of each stem was allowed to protrude from the water. An equal number of organisms was introduced into each jar. The surface of the water was then covered with a mixture of paraffine and beeswax. The animals in the jar where the stems protruded through the seal invariably lived longer. The periods for the beetles were about 1 and 3 days respectively.

Light.—The pond is fairly well lighted throughout its entire depth during the day except when it is covered with snow. The light is reduced considerably by the growth of Typha. Kofoid ('04) found that, with the development of phanerogams in one of the backwater ponds tributary to the Illinois River, there was a marked reduction in the plankton. Some comparative observations were made on a pond about five miles west of this one. It has about the same area and depth but there is no Typha growing in it. Although no quantitative methods were applied, cladocera, copepoda, and chlorophyceæ were much more in evidence in it during September, '09, than in the pond under discussion. It seems probable that the reduction of the light by the Typha growth has resulted in fewer species and individuals developing in this pond.

On Jan. 11, 1909, the ice was partially melted. Openings had formed in the ice around the Typha stems and about 2½ to 3 inches of water stood above the remaining ice sheet. Cyclops was quite abundant in this upper layer of water which was certainly due to their being phototactic. It was the only organism detected. A lowering of the temperature under such conditions would certainly destroy many individuals. Thus an adaptation presumed to be beneficial under one condition becomes destructive under certain other conditions.

Food Relations.—Regarding the nutrition of aquatic organisms there are two theories, which, although not mutually exclusive, are essentially different.

The older one is that the ultimate source of food is chlorophyl bearing plants and the various forms of bacteria which produce nitrates and nitrites. The materials thus elaborated or their derivatives are ingested into food vacuoles, gastrovascular spaces, or alimentary tracts of animals, where they are acted on by secretions of the animal, reduced to a solution and absorbed. This theory has been assumed by most zoölogists in their discussions of food relations, and it is the most fundamental assumption in the investigations now being prosecuted by the International Fishery Organization.

The second theory is that proposed by Pütter ('08). He holds that the nutrition of many aquatic forms is essentially different from that of land animals. He shows that water contains large amounts of carbon compounds in solution and demonstrates experimentally that this is the source of nutrition for a sponge, *Suberites domuncula* and a holothurian (*Cucumaria grubei*). In this paper and two subsequent ones, he extends his theory to include representatives of every phylum of aquatic animals.

Possibly foreseeing the difficulty offered by the fact that in general, waste compounds of animals are less complex than their food, he suggests that a photochemical process may take place in aquatic animals, analogous to that of chlorophyl bearing plants. "Ob die gelösten Stoffe, die den niederen Tieren als Nahrung dienen, soviel Energie enthalten, dasz der Abbau durch Spaltungen und Oxydationen allein hinreicht, um den Energiebedarf der Tiere zudecken, oder ob hier in einer weiteren Analogie mit dem Stoffwechsel der Pflanze strahlende Energie ausgenutzt wird, um durch photochemische Prozesse aus den aufgenommenen gelösten Stoffen Substanzen von höherem Energiegehalt herzustellen, das ist eine Frage von so hoher prinzipieller Bedeutung, dasz, die wenigen Erfahrungen, die zu ihrer Erörterung gegenwärtig beigebracht werden könnten, nicht hinreichend zur Entscheidung sind."

With the exception of *Simocephalus vetellus*, the methods of Pütter have not been applied to species found in this pond. Wolff, '09, was able to show that *Simocephalus vetellus* could develop in a medium free from nutrition in the form of solids (geformte Nährung).

Without denying the possibility that aquatic animals derive some food from the water by direct absorption of nutrient solutions, it may be stated with certainty that the higher animals of this pond for the most part utilize solid food. This statement is based on observations on feeding and the examination of alimentary tracts.

In this discussion of the food relations of these animals, I shall ignore Pütter's alternative. If it be subsequently proven that the ingestion of food is merely incidental, it will also establish their complete independences so far as food relations are concerned.

I have tried to express in the accompanying diagram some of the important food relations between the organisms of the pond. These relations are very complicated because of the omniverous habits of some of the forms. Many of the forms derive their nutrition in part from the dead organic matter in the pond, to which all of the forms contribute. The ultimate food sources in the pond are (1) water; (2) carbon dioxide in solution in the water (derived from the air above the water); (3) nitrogen, free and in simple compounds, such as ammonia; (4) foreign organisms accidentally falling into the pond. e. g., insects. The formation of nitrates from simple nitrogen compounds was established by the well known work of Winogradsky ('89). He demonstrated two kinds of bacteria, one forming nitrous acid, another changing this to nitric acid which is neutralized by carbonates already present. This process may be assumed to form the first step in the proteid synthesis in this pond.

These bacteria and those present in the decaying organic matter of the pond are eaten by the flagellates and ciliates. The ciliates also use the flagellates for food. The carbohydrates of this group are derived from the dead organic matter in the pond. The synthesis of carbon dioxide and water into carbohydrates is of course due to chlorophyl bearing plants. These plants consist of desmids, diatoms, filamentous algæ and phanerogams. The inclusion of diatoms and the smaller desmids by Difflugia has been demonstrated by observation. *Simocephalus* is the only animal in the pond that is dependent wholly upon algæ for food. It may be able to adapt itself to some other food, but in this habitat its alimentary canal contains nothing else. It has not been demonstrated that any organism eats the living Typha plants except that the snails sometimes eat the more tender shoots. *Limnodrilus* lives among the roots but its alimentary tract contains rather finely comminuted material, some of which is clearly decaying plant stems. *Cypridopsis vidua* Brady feeds on the material which forms a slimy layer over the Typha stems, sticks, etc. Of course, this layer includes some organisms; however, their inclusion is accidental. I am sure they do not select algæ. *Simocephalus*, *Limnodrilus* and ostracoda are eaten by dragon fly nymphs. Naturally this is difficult to observe in the pond. In order to eliminate the unnatural instincts that develop in an aquarium, a deep soup plate was kept at the pond, into which dragon fly nymphs and other forms were introduced immediately on being taken from the pond. The white background made observation easy and accurate, and one may be reasonably sure that the feeding instincts exhibited were natural. The nymphs experimented with belonged to the family Libellulidæ. The preference of the dragon fly nymphs is indicated by the order

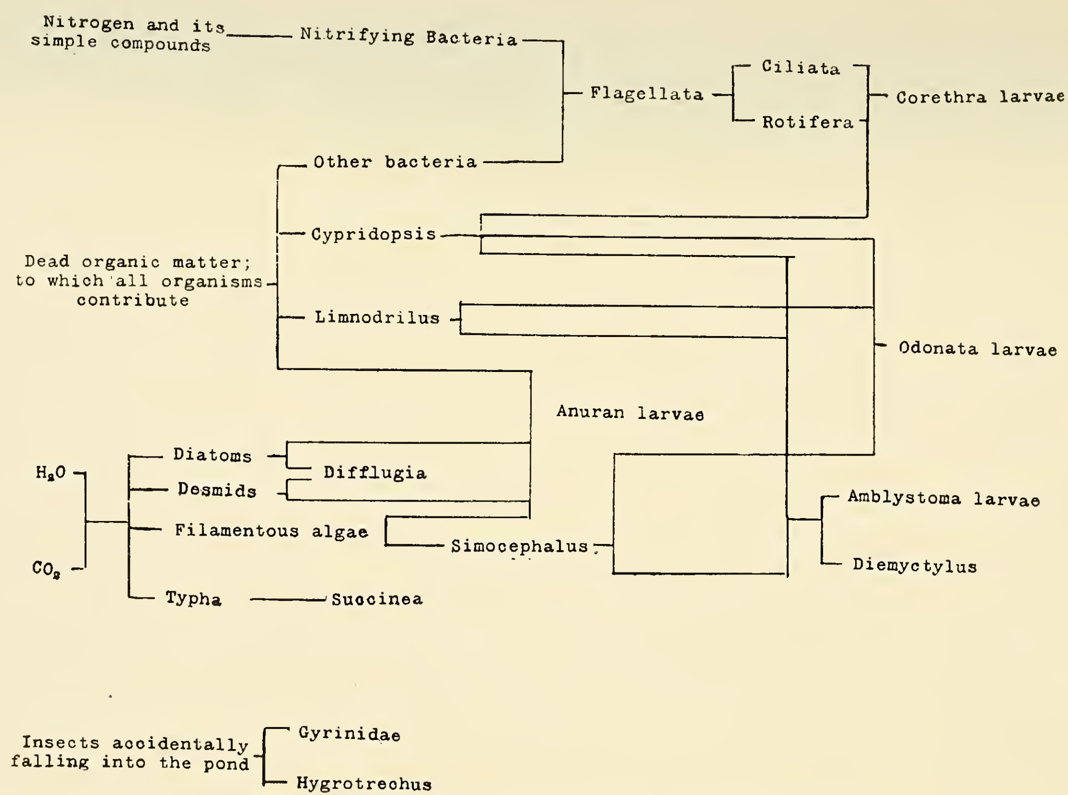

FIG. VI. Indicating the principal food relations existing between the organisms in the pond.

in which the forms are named. *Limnodrilus* is eaten voraciously by the *Amblystoma* larvæ and by *Diemyctylus*. *Diemyctylus* has been observed a few times to take *Simocephalus*.

The insects that accidentally fall into the pond are captured by the Gyrinidæ and *Hygrotrechus*.

The *Corethra* larvæ feed on ostracoda and possibly other forms in this pond. Miall ('95, page 115) says, "Corethra larvæ feed upon small aquatic animals such as Ephemera-larvæ, Daphnia, or Cypris." The Hydrophylidæ feed on the decaying organic matter. The Dytiscidæ have not been observed feeding in this pond, although they are known to be carniverous, Kellogg ('04, p. 258). The larvæ of the Anura of this pond are rather omniverous. They eat filamentous algæ, desmids, diatoms, protozoa, ostracoda and decaying organic material. There seems to be very little if any discrimination in the selection of food. Not all of the material eaten contributes to the nutrition of these larvæ. The rate of digestion in cold blooded vertebrates has been shown by Riddle ('09) to vary directly with temperature. However, at ordinary temperatures many organisms pass through their alimentary tracts unchanged. In the faeces of larvæ placed in tap water, *Oedogonium, Closterium* and *Doccidium* are common. From the alimentary tracts of larvæ kept for 5 days in water, which had been previously boiled, have been taken *Euglena, Phacus, Spirogyra, Oedogonium, Closterium, Doccidium*. The filamentous algæ and *Closterium* were in part disintegrated. The *Euglenæ* were very active. In another series that was kept 10 days, Ostracoda (Candona?) were found alive in the large intestine of six specimens. These facts indicate that the nutrition is derived from dead organic matter (filamentous algæ and Closterium) and that the inclusion of other, living organisms is accidental.

In connection with food relations may be mentioned the mechanical comminution of plant debris. When plants die in the pond, they stand for a time, then fall on the surface of the water where they float for a while and then sink. During this period they are being softened by the processes of decay. Their comminution is due to the action of the Ostracoda, especially *Cypridopsis* and the aquatic beetles belonging to the families Hydrophylidæ and Dytiscidæ. The specific gravity of the former is slightly greater than water and that of the latter slightly less. A piece of floating plant stem is covered with Ostracoda. A bit of the stem is often torn off by one of these ostracods. The ostracod remains attached to it until it reaches the bottom when it is released. The process is reversed in the case of the beetles. They clasp a bit of sunken plant stem in order to keep them at the bottom. A part of this often separates and is carried toward the surface. It is by the innumerable repetition of these processes that the mass of finely comminuted particles at the bottom of the pond is formed.

COMPARISON WITH LAKES.

The fundamental difference between this pond and a lake is that of dimension. It has a smaller area and is not so deep. A pond has no abysmal region but has some of the characters of the littoral and pelagic regions of lakes. From this fundamental difference, secondary differences arise. The changes in level affect the relative depth much more in ponds than in lakes. The lowering of the level of a lake one-half meter would not affect its fauna to any marked degree, while the same difference in level occurring in a pond whose depth was a meter or less would profoundly influence the organisms inhabiting it.

The temperature in all parts of the pond is near that of the atmosphere above it. In this it resembles closely the shallow littoral region of some lakes, e. g., "barren shoals" of Walnut Lake (Hankinson, '07). So far as observed the difference in temperature in different parts of the pond at any given time has not exceeded 2° C. It is practically holothermous, the thermocline and associated phenomena are absent.

Forel ('04) has shown in the case of Lake Geneva, that the littoral region is one of variety. This fact is perfectly familiar to all students of lakes. In the same lake, one part of this region may be covered with rushes (*Scirpus*), another by water lilies (*Nymphea*), another by *Potamogeton,* while another may be barren sand or rock or an equally barren marl bed.

An individual pond lacks this variety. It is in this particular that this pond and others like it differ most from the littoral region of lakes. (It is more nearly comparable to a limited section of a lake shore.) If Typha is introduced, it soon spreads over the whole area, limiting the light, excluding other phanerogams, and developing very uniform conditions over the entire pond. If a pond is developed on the side of a hill so that silt is carried into it, a muddy, barren condition exists over the whole area. Ponds in the woods rarely develop aquatic seed plants; the leaves from the surrounding trees cover the bottom so that a very distinct but uniform condition is developed. Besides their limited area, a second cause of this uniformity is their sudden formation. During the summer of '08, four miles east of Mitchell, Indiana, an open sinkhole containing several acres became sealed. With the first rain a pond with an area of about one acre was formed. This is the typical phenomenon in the formation of solution ponds. It may take a very long time for the solution cone or sinkhole to form, but when the opening at its base becomes sealed, the pond reaches its maximum depth quite suddenly. The result is that an aquatic habitat is formed with no aquatic fauna. The first forms introduced into a pond at this stage have no competition and soon take possession of the entire area, thus making it more difficult for a related form to establish itself. Another difference between these ponds and lakes (which seems to be due to their fundamental difference in size) is the paucity of species in the former when compared with the latter. It seems probable that, other things being equal, the larger the lake, the greater the variety in the fauna. Forel ('04) reports 22 species and 10 varieties of cladocera, 9 ostracoda and 12 gastropoda from Lake Geneva, while from the smaller Plöner See, Zacharias ('93) reports 20 species and varieties of cladocera, one ostracoda and 10 gastropoda. Burckhardt ('00) observes that the plankton of the Alpenacher See contains fewer species than the Vierwaldstädtersee. Dr. W. Halbfass collected from a number of lakes in northern Germany and sent the material to Zacharias for examination. The lists show only one cladoceran from Dolgensee bei Neustettin, a very small body of water, while Wilmsee, a much larger lakelet, contained six. The faunal list for any lake that has been explored with care, is much greater than that of this pond.

This is due to the uniformity of conditions that prevails over the entire area of a given pond at a particular period, and to the fact that the pond after its formation, changes very rapidly, thus making it suited for a particular species for a relatively short period. If the species is not introduced during the period in which conditions are adapted to it, it can never develop.

In a lake, conditions are relatively static and a large per cent of the forms capable of developing in it at a given stage in its history, succeed in reaching it, while in a pond this per cent is much smaller. Forel ('04, p. 408) states that the similarity of the microfauna (i. e., passive migrants) of one lake to that of another is due to the "reaction reciproque d'un lac a l'autre." It is evident that this can occur only when similar conditions (e. g., pelagic) are present in the different lakes. In lakes this similarity may exist in certain parts during the major part of their existence. In ponds the period for this reciprocal reaction is very limited.

Although a single pond contains relatively few species, all the ponds in an area of several square miles show a much greater variety.

Many ponds have been examined but detailed data concerning them have not yet been collected. However, the following note will illustrate what is meant. On Jan. 11, 1910, pond No. 1 P contained *Cyclops bicuspidatus,* Chydorus sphaericus, Cypridopsis vidua and alona. Pond No. 2 T contained *Cyclops serrulatus, C. leuckarti;* and an unidentified Daphnid. Pond No. 6 P contained a few *Cyclops serrulatus* and an enormous number of *Bosmina cornuta.* Other groups of organisms show an equal variety.

RELATION TO CAVE PLANKTON.

This variety in the fauna of different ponds has an important bearing upon the relation of pond plankton to that of caves. That the plankton of the cave streams of this region is derived from certain of these ponds is well established. Only a small number of the organisms in any pond are able to withstand the inimical cave conditions. I have never found all the species reported from the Shawnee Cave stream in any one pond.

These facts indicate that the cave plankton is a composite of such organisms of the contributing ponds as are able to withstand cave conditions. It is probable that the greater the number of contributing ponds, the richer will be the fauna at the outlet of the cave stream.

The relation of these solution ponds to a cave stream is quite comparable to the relation of backwater lakes, bayous, oxbow cutoffs, etc., to the river in whose valley they lie. Kofoid ('03, p. 546) states concerning the Illinois River, "The plankton indigenous to the channel itself is of small volume as compared with that contributed from the backwaters." There is, however, this difference. In the cave the processes of growth and reproduction are very much inhibited, while in the river they continue or may even be increased. Kofoid (lc) has shown that during periods of low water, the river may contain more plankton than the contributing waters. This condition never exists in cave streams and obviously never can exist.

UNSOLVED PROBLEMS.

This study, while it gives a fairly complete picture of a particular pond and establishes some general notions concerning ponds of this type, is to be regarded as opening up a new corner in the field of freshwater biology, rather than exhausting any part of it. The fauna of solution ponds needs to be more carefully and generally explored. The life history of many of the species is quite unknown. Experimental studies on the effects of varied conditions upon some of the organisms are certain to yield results. The details of the mode of dispersal are very imperfectly known in many forms.

The most important general investigation, it seems, is to carefully select a series of ponds having different combinations of environmental factors, i. e., area, depth, shade, plant growth, wash, etc., and to make a series of simultaneous observations extending over at least one year. Then by a process of elimination, determine the effect of these factors.

I desire to express my obligations to Prof. C. H. Eyenmann and Prof. Charles Zeleny for their valuable suggestions and criticisms.

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