PROCEEDINGS

OF THE

Indiana Academy of Science

1897.

EDITOR, - - C. A. WALDO.

ASSOCIATE EDITORS:

J. C. ARTHUR, W. A. NOYES, C. H. EIGENMANN, A. W. DUFF,
V. F. MARSTERS, A. W. BUTLER, W. S. BLATCHLEY.

INDIANAPOLIS, IND.
1898.

INDIANAPOLIS:
WM. B. BURFORD, PRINTER,
1898.

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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.]

Preamble.

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 body, assist in the direction and execution of any investigation within its province, without pecuniary gain to the Academy, provded 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,

Publication of the reports of the Indiana Academy of Science.

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.

Editing reports.

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 services, 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

Number of printed reports.

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.

Proviso.

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 Indiana 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.

Disposition of reports.

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.

Emergency.

An Act for the protection of birds, their nests and eggs.

[Approved March 5, 1891.]

Section 1. *Be it enacted by the General Assembly of the State of Indiana*, That it shall be unlawful for any person to kill any wild bird other than a game bird, or purchase, offer for sale any such wild bird after it has been killed, or to destroy the nests or the eggs of any wild bird.

Birds.

Sec. 2. For the purpose of this act the following shall be considered game birds: the Anatidæ, commonly called swans, geese, brant, and river and sea ducks; the Rallidæ, commonly known as rails, coots, mudhens, and gallinules; the Limicolæ, commonly

Game Birds.

known as shore birds, plovers, surf birds, snipe, woodcock and sandpipers, tattlers and curlews; the Gallinæ, commonly known as wild turkeys, grouse, prairie chickens, quail, and pheasants, all of which are not intended to be affected by this act.

Penalty.

SEC. 3. Any person violating the provisions of Section 1 of this act shall, upon conviction, be fined in a sum not less than ten nor more than fifty dollars, to which may be added imprisonment for not less than five days nor more than thirty days.

Permits.

SEC. 4. Sections 1 and 2 of this act shall not apply to any person holding a permit giving the right to take birds or their nests and eggs for scientific purposes, as provided in Section 5 of this act.

Permits to Science.

SEC. 5. Permits may be granted by the Executive Board of the Indiana Academy of Science 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 said Board written testimonials from two well known scientific men certifying to the good character and fitness of said applicant to be entrusted with such privilege and pay to said Board one dollar to defray the necessary expenses attending the granting of such permit, and must file with said Board a

Bond.

properly executed bond in the sum of two hundred dollars, signed by at least two responsible citizens of the State as sureties. The bond shall be forfeited to the State and the permit become

Bond forfeited.

void upon proof that the holder of such permit has killed any bird or taken the nests or eggs of any bird for any other purpose than that named in this section and shall further be subject for each offense to the penalties provided in this act.

Two years.

SEC. 6. The permits authorized by this act shall be in force for two years only from the date of their issue, and shall not be transferable.

Birds of prey.

SEC. 7. The English or European house sparrow (passer domesticus), crows, hawks, and other birds of prey are not included among the birds protected by this act.

Acts repealed.

SEC. 8. All acts or parts of acts heretofore passed in conflict with the provisions of this act are hereby repealed.

Emergency.

SEC. 9. An emergency is declared to exist for the immediate taking effect of this act, therefore the same shall be in force and effect from and after its passage.

OFFICERS, 1897–98.

PRESIDENT,

C. A. WALDO.

VICE-PRESIDENT,

CARL H. EIGENMANN.

SECRETARY,

JOHN S. WRIGHT.

ASSISTANT SECRETARY,

A. J. BIGNEY.

PRESS SECRETARY,

GEO. W. BENTON.

TREASURER,

J. T. SCOVELL.

EXECUTIVE COMMITTEE.

C. A. Waldo,
C. H. Eigenmann,
John S. Wright,
A. J. Bigney,
G. W. Benton,
J. T. Scovell,
Thomas Gray,
Stanley Coulter,
Amos W. Butler,
W. A. Noyes,
J. C. Arthur,
J. L. Campbell,
O. P. Hay,
T. C. Mendenhall,
John C. Branner,
J. P. D. John,
John M. Coulter,
David S. Jordan.

CURATORS.

BOTANY .... J. C. Arthur.
ICHTHYOLOGY .... C. H. Eigenmann.
HERPETOLOGY, MAMMALOGY, ORNITHOLOGY ...... Amos W. Butler.
ENTOMOLOGY .... W. S. Blatchley.

COMMITTEES, 1897-98.

PROGRAM.

D. W. Dennis, A. J. Bigney.

MEMBERSHIP.

R. Ellsworth Call, D. W. Dennis, C. R. Dryer.

NOMINATIONS.

W. S. Blatchley, W. A. Noyes, W. E. Stone.

AUDITING.

Geo. L. Roberts, R. Ellsworth Call.

STATE LIBRARY.

C. A. Waldo, W. A. Noyes, A. W. Butler.
A. W. Duff, J. S. Wright.

LEGISLATION FOR THE RESTRICTION OF WEEDS.

J. C. Arthur, Stanley Coulter, J. S. Wright.

PROPAGATION AND PROTECTION OF GAME AND FISH.

C. H. Eigenmann, A. W. Butler, W. S. Blatchley.

EDITOR.

C. A. Waldo.

DIRECTORS OF BIOLOGICAL SURVEY.

C. H. Eigenmann, V. F. Marsters, J. C. Arthur.

RELATIONS OF THE ACADEMY TO THE STATE.

C. A. Waldo, A. W. Butler, C. H. Eigenmann.

GRANTING PERMITS FOR COLLECTING BIRDS.

A. W. Butler, C. H. Eigenmann, W. S. Blatchley.

DISTRIBUTION OF THE PROCEEDINGS.

A. W. Butler, W. A. Noyes, C. A. Waldo.
C. H. Eigenmann, V. F. Marsters,
J. S. Wright

OFFICERS OF THE INDIANA ACADEMY OF SCIENCE.

	President.	Secretary.	Asst. Secretary.	Press Secretary.	Treasurer.
1885–6	David S. Jordan.	Amos W. Butler.	....	....	O. P. Jenkins.
1886–7	John M. Coulter.	Amos W. Butler.	....	....	O. P. Jenkins.
1887–8	J. P. D. John.	Amos W. Butler.	....	....	O. P. Jenkins.
1888–9	John C. Branner.	Amos W. Butler.	....	....	O. P. Jenkins.
1889–90	T. C. Mendenhall.	Amos W. Butler.	....	....	O. P. Jenkins.
1890–1	O. P. Hay.	Amos W. Butler.	....	....	O. P. Jenkins.
1891–2	J. L. Campbell.	Amos W. Butler.	....	....	C. A. Waldo.
1892–3	J. C. Arthur.	Amos W. Butler.	Stanley Coulter. W. W. Norman.	....	C. A. Waldo.
1893–4	W. A. Noyes.	C. A. Waldo.	W. W. Norman.	....	W. P. Shannon.
1894–5	A. W. Butler.	John S. Wright.	A. J. Bigney.	....	W. P. Shannon.
1895–6	Stanley Coulter.	John S. Wright.	A. J. Bigney.	....	W. P. Shannon.
1896–7	Thomas Gray.	John S. Wright.	A. J. Bigney.	....	W. P. Shannon.
1897–8	C. A. Waldo.	John S. Wright.	A. J. Bigney.	Geo. W. Benton.	W. P. Shannon. J. T. Scovell.

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 programmes 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 specially 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 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 evening of one of the days of the meeting at the expiration of his term of office.

3. The press secretary shall attend to securing 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.

J. C. Arthur	*1893	Lafayette.
P. S. Baker	1893	Greencastle.
George W. Benton	1896	Indianapolis.
A. J. Bigney	1897	Moore's Hill.
A. W. Bitting	1897	Lafayette.
W. S. Blatchley	1893	Indianapolis.
J. C. Branner	1893	Stanford University, Cal.
Wm. Lowe Bryan	1895	Bloomington.
A. W. Butler	1893	Indianapolis.
R. E. Call	1894	Lawrenceburg.
J. L. Campbell	1893	Crawfordsville.
John M. Coulter	1893	Chicago, Ill.
Stanley Coulter	1893	Lafayette.
D. W. Dennis	1895	Richmond.
C. R. Dryer	1897	Terre Haute.
A. Wilmer Duff	1896	Lafayette.
C. H. Eigenmann	1893	Bloomington.
A. L. Foley	1897	Bloomington.
Katherine E. Golden	1895	Lafayette.
W. F. M. Goss	1893	Lafayette.
Thos. Gray	1893	Terre Haute.
A. S. Hathaway	1895	Terre Haute.
O. P. Hay	1893	Washington, D. C.
H. A. Huston	1893	Lafayette.
J. P. D. John	1893	Greencastle.
D. S. Jordan	1893	Stanford University, Cal.
Robert E. Lyons	1896	Bloomington.
V. F. Marsters	1893	Bloomington.
C. L. Mees	1894	Terre Haute.
T. C. Mendenhall	1893	Worcester, Mass.

*Date of election.

Joseph Moore	*1896	Richmond.
D. M. Mottier	1893	Bloomington.
W. A. Noyes	1893	Terre Haute.
L. J. Rettger	1896	Terre Haute.
J. T. Scovell	1894	Terre Haute.
†W. P. Shannon	1893	Greensburg.
Alex. Smith	1893	Chicago, Ill.
W. E. Stone	1893	Lafayette.
M. B. Thomas	1893	Crawfordsville.
L. M. Underwood	1893	New York City.
T. C. Van Nuys	1893	Bloomington.
C. A. Waldo	1893	Lafayette.
F. M. Webster	1894	Wooster, O.
H. W. Wiley	1895	Washington, D. C.
John S. Wright	1894	Indianapolis.

NON-RESIDENT MEMBERS.

D. H. Campbell	Stanford University, Cal.
B. W. Evermann	Washington, D. C.
Charles H. Gilbert	Stanford University, Cal.
C. W. Green	Stanford University, Cal.
C. W. Hargitt	Syracure, N. Y.
Edward Hughes	Stockton, Cal.
O. P. Jenkins	Stanford University, Cal.
J. S. Kingsley	Tufts College, Mass.
Alfred Springer	Cincinnati, O.
Robert B. Warder	Washington, D. C.
Ernest Walker	Clemson College, S. C.

ACTIVE MEMBERS.

Frederick W. Andrews	Bloomington.
R. J. Aley	Bloomington.
George H. Ashley	Indianapolis.
Timothy H. Ball	Crown Point.

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* Date of election.
† Deceased, December 16, 1897.

C. L. Barnes .... Indianapolis.
J. A. Bergstrom .... Bloomington.
Alexander Black .... Greencastle.
Edwin M. Blake .... Lafayette.
Lee F. Bennett .... Valparaiso.
Donaldson Bodine .... Crawfordsville.
M. A. Brannon .... Grand Forks, N. D.
Frank P. Bronson .... Indianapolis.
Charles C. Brown .... Indianapolis.
H. L. Bruner .... Irvington.
A. Hugh Bryan .... Indianapolis.
Severance Burrage .... Lafayette.
J. B. Burris .... Cloverdale.
Noble C. Butler .... Indianapolis.
Ada C. Campbell .... South Bend.
J. T. Campbell .... Rockville.
E. J. Chansler .... Bicknell.
Fred. M. Chamberlain .... Bloomington.
Walter W. Chipman .... Warsaw.
J. Fred Clearwaters .... Indianola, Ill.
George Clements .... Crawfordsville.
H. J. Clements .... Washington.
Charles Clickener .... Tangier.
U. O. Cox .... Mankato, Minn.
Albert B. Crowe .... Ft. Wayne.
M. E. Crowell .... Indianapolis.
Glenn Culbertson .... Hanover.
Will Cumback .... Greensburg.
Alida M. Cunningham .... Lafayette.
H. S. Cunningham .... Indianapolis.
*George L. Curtiss .... Columbus.
B. M. Davis .... Los Angeles, Cal.
Martha Doan .... Westfield.
J. P. Dolan .... Syracuse.
Joseph Eastman .... Indianapolis.
E. G. Eberhardt .... Indianapolis.

* Deceased, March 31, 1898.

M. N. Elrod .... Columbus.
F. L. Emory .... Morgantown, W. Va.
Percy Norton Evans .... Lafayette.
Samuel G. Evans .... Evansville.
Carlton G. Ferris .... Big Rapids, Mich.
E. M. Fisher .... Urmeyville.
J. J. Flather .... Lafayette.
J. R. Francis .... Indianapolis.
Austin Funk .... Bloomington.
J. B. Garner .... Crawfordsville.
Robert G. Gillum .... Terre Haute.
U. F. Glick .... Newbern.
Michael J. Golden .... Lafayette.
W. E. Goldsborough .... Lafayette.
S. S. Gorby .... Franklin.
Vernon Gould .... Rochester.
J. C. Gregg .... Brazil.
Alden H. Hadley .... Melbourne, Fla.
Wm. Perry Hay .... Washington, D. C.
Franklin W. Hays .... Indianapolis.
E. H. Heacock .... Topeka, Kas.
Chas. A. Helvie .... Chicago.
Flora Herr .... Bloomington.
Robert Hessler .... Indianapolis.
J. A. Hill ....
T. E. Hibben .... Indianapolis.
J. W. Hubbard .... Bloomington.
Lucius M. Hubbard .... South Bend.
Alex. Jameson .... Indianapolis.
A. E. Jessup .... Carmel.
Sylvester Johnson .... Irvington.
W. B. Johnson .... Franklin.
Chancey Juday .... Bloomington.
William J. Karslake .... Irvington.
D. S. Kelley .... Jeffersonville.
O. L. Kelso .... Terre Haute.
Arthur Kendrick .... Terre Haute.
E. M. Kindle .... Bloomington.

Ph. Kirsch	Columbia City.
Charles T. Knipp	Bloomington.
Thomas Large	Evansville.
Daniel Layman	Indianapolis.
John Levering	Lafayette.
V. H. Lockwood	Indianapolis.
William A. Macbeth	Terre Haute.
Cora March	Lawrenceburg.
Herbert W. McBride	Indianapolis.
Robert Wesley McBride	Indianapolis.
Kate McCarthy	Wabash.
Rousseau McClellan	Bloomington.
D. T. McDougal	Minneapolis, Minn.
J. W. Marsee	Indianapolis.
G. W. Martin	Indianapolis.
Julius B. Meyer	Lafayette.
O. M. Meyncke	Brookville.
Franklin S. Miller	Brookville.
John A. Miller	Bloomington.
W. J. Moenkhaus	San Paulo, Brazil.
G. T. Moore	Cambridge, Mass.
J. P. Naylor	Greencastle.
Charles E. Newlin	Irvington.
John F. Newsom	Elizabethtown.
E. W. Olive	Indianapolis.
J. H. Oliver	Indianapolis.
D. A. Owen	Franklin.
Rollo J. Peirce	
W. H. Peirce	Chicago, Ill.
*Elwood Pleas	Dunreith.
James A. Price	Bloomfield.
Frank A. Preston	Indianapolis.
A. H. Purdue	Fayetteville, Ark.
Ryland Ratliff	Fairmount.
H. G. Reddick	Bloomington.
Bessie C. Ridgley	South Bend.

*Deceased, December 30, 1897.

D. C. Ridgley.................................Chicago, Ill.
Curtis A. Rinson.................................Bloomington.
George L. Roberts.................................Greensburg.
Adolph Rodgers.................................New Castle.
John F. Schnaible.................................Lafayette.
C. E. Schafer.................................Huntington.
E. A. Schultze.................................Ft. Wayne.
Howard Schurmann.................................Indianapolis.
John W. Shepherd.................................Terre Haute.
Claude Siebenthal.................................Bloomington.
G. W. Sloan.................................Indianapolis.
J. R. Slonaker.................................Bloomington.
Richard A. Smart.................................Lafayette.
Harold B. Smith.................................Worcester, Mass.
Theo. W. Smith.................................Indianapolis.
Lillian Snyder.................................Lafayette.
F. P. Stauffer.................................Logansport.
M. C. Stevens.................................Lafayette.
H. M. Stoops.................................Brookville.
Joseph Swain.................................Bloomington.
William Stewart.................................Lafayette.
George A. Talbert.................................West Superior, Wis.
Frank B. Taylor.................................Ft. Wayne.
S. N. Taylor.................................West Lafayette.
Erastus Test.................................Lafayette.
F. C. Test.................................Chicago, Ill.
J. F. Thompson.................................Richmond.
William M. Thrasher.................................Irvington.
A. L. Treadwell.................................Oxford, Ohio.
Daniel J. Troyer.................................Goshen.
W. P. Turner.................................Lafayette.
A. B. Ulrey.................................North Manchester.
W. B. Van Gorder.................................Knightstown.
Arthur C. Veatch.................................Rockport.
H. S. Voorhees.................................Brookville.
J. H. Voris.................................Bloomington.
F. A. Walker.................................Anderson.
W. O. Wallace.................................Wabash.

Fred C. Whitcomb	Delphi.
William M. Whitten	South Bend.
J. R. Wiest	Richmond.
Mae Woldt	Irvington.
W. L. Wood	Covington.
William Watson Woollen	Indianapolis.
A. J. Woolman	Duluth, Minn.
J. F. Woolsey	Indianapolis.
P. A. Yoder	Vincennes.
A. C. Yoder	Vincennes.
O. B. Zell	Clinton.

Fellows	44
Non-resident members	11
Active members	160
Total	215
Deaths	3

In Memoriam.

WILLIAM POLLOCK SHANNON,

(Treasurer of the Indiana Academy of Science,
1893 to 1897.)

Died, Greensburg, Indiana, December Sixteenth, 1897.

In Memoriam.

GEORGE LEWIS CURTISS,

Died, Naples, Italy, March Thirty-first, 1898.

In Memoriam.

ELWOOD PLEAS,

Died, Dunreith, December Thirtieth, 1897.

LIST OF FOREIGN CORRESPONDENTS.

AFRICA.

Dr. J. Medley Wood, Natal Botanical Gardens, Berea Durban, South Africa.

South African Philosophical Society, Cape Town, South Africa.

ASIA.

China Branch Royal Asiatic Society, Shanghai, China.

Asiatic Society of Bengal, Calcutta, India.

Geological Survey of India, Calcutta, India.

Indian Museum of India, Calcutta, India.

India Survey Department of India, Calcutta, India.

Deutsche Gesellschaft für Natur und Volkerkunde Ostasiens, Tokio, Japan.

Imperial University, Tokio, Japan.

Koninklijke Naturkundige Vereeniging in Nederlandsch-Indie, Batavia, Java.

Hon. D. D. Baldwin, Honolulu, Hawaiian Islands.

EUROPE.

V. R. Tschusizu Schmidhoffen, Villa Tannenhof, Halle in Salzburg, Austria.

Herman von Vilas, Innsbruck, Austria.

Ethnologische Mittheilungen aus Ungarn, Budapest, Austro-Hungary.

Mathematische und Naturwissenschaftliche Berichte aus Ungarn, Budapest, Austro-Hungary.

K. K. Geologischen Reichssanstalt, Vienna (Wien), Austro-Hungary.

K. U. Naturwissenschaftliche Gesellschaft, Budapest, Austro-Hungary.

Naturwissenschaftlich-Medizinischer Verein in Innsbruck (Tyrol), Austro-Hungary.

Editors "Termeszetrajzi Fuzetk," Hungarian National Museum, Budapest, Austro-Hungary.

Dr. Eugen Dadai, Adj. am Nat. Mus., Budapest, Austro-Hungary.

Dr. Julius von Madarasz, Budapest, Austro-Hungary.

K. K. Naturhistorisches Hofmuseum, Vienna (Wien), Austro-Hungary.

Ornithological Society of Vienna (Wien), Austro-Hungary.

Zoölogische-Botanische Gesellschaft in Wien, Wien, Austro-Hungary.

Dr. J. von Csato, Nagy Enyed, Austro-Hungary.

Malacological Society of Belgium, Brussells, Belgium.

Royal Academy of Science, Letters and Fine Arts, Brussells, Belgium.

Royal Linnean Society, Brussells, Belgium.

Societé Belge de Geologie, de Palaeontologie et Hydrologie, Brussells, Belgium.

Societé Royale de Botanique, Brussells, Belgium.

Societé Geologique de Belgique, Liège, Belgium.

Prof. Christian Frederick Lutken, Copenhagen, Denmark.

Bristol Naturalists' Society, Bristol, England.

Geological Society of London, London, England.

Linnean Society of London, London, England.

Liverpool Geological Society, Liverpool, England.

Manchester Literary and Philosophical Society, Manchester, England.

"Nature," London, England.

Royal Botanical Society, London, England.

Royal Geological Society of Cornwall, Penzance, England.

Royal Microscopical Society, London, England.

Zoölogical Society, London, England.

Lieut.-Col. John Biddulph, 43 Charing Cross, London, England.

Dr. G. A. Boulenger, British Mus. (Nat. Hist.), London, England.

F. DuCane Godman, 10 Chandos St., Cavendish Sq., London, England.

Hon. E. L. Layard, Budleigh Salterton, Devonshire, England.

Mr. Osbert Salvin, Hawksfold, Fernshurst, Haslemere, England.

Mr. Howard Saunders, 7 Radnor Place, Hyde Park, London W., England.

Phillip L. Sclater, 3 Hanover Sq., London W., England.

Dr. Richard Bowlder Sharpe, British Mus. (Nat. His.), London, England.
Prof. Alfred Russell Wallace, Corfe View, Parkstone, Dorset, England.

Botanical Society of France, Paris, France.
Ministērie de l'Agriculture, Paris, France.
Societé Entomologique de France, Paris, France.
L'Institut Grand Ducal de Luxembourg, Luxembourg, Lux, France.
Soc. de Horticulture et de Botan. de Marseille, Marseilles, France.
Societé Linneenne de Bordeaux, Bordeaux, France.
La Soc. Linneenne de Normandie, Caen, France.
Soc. des Naturelles, etc., Nantes, France.
Zoölogical Society of France, Paris, France.
Baron Louis d' Hamonville, Meurthe et Moselle, France.
Prof. Alphonse Milne-Edwards, Rue Cuvier, 57, Paris, France.

Botanischer Verein der Provinz Brandenburg, Berlin, Germany.
Deutche Geologische Gesellschaft, Berlin, Germany.
Entomologischer Verein in Berlin, Berlin, Germany.
Journal für Ornithologie, Berlin, Germany.
Prof. Dr. Jean Cabanis, Alte Jacob Strasse, 103 A., Berlin, Germany.
Augsburger Naturhistorischer Verein, Augsburg, Germany.
Count Hans von Berlspsen, Münden, Germany.
Braunschweiger Verein für Naturwissenschaft, Braunschweig, Germany.
Bremer Naturwissenschaftlicher Verein, Bremen, Germany.
Kaiserliche Leopoldische-Carolinische Deutsche Akademie der Naturforcher, Halle, Saxony, Germany.
Königlich-Sächsische Gesellschaft der Wissenschaften, Mathematische-Physische Classe, Leipzig, Saxony, Germany.
Naturhistorische Gesellschaft zu Hanover, Hanover, Prussia, Germany.
Naturwissenschaftlicher Verein in Hamburg, Hamburg, Germany.
Verein für Erdkunde, Leipzig, Germany.
Verein für Naturkunde, Weisbaden, Prussia.

Belfast Natural History and Philosophical Society, Belfast, Ireland.
Royal Dublin Society, Dublin.

Societa Entomologica Italiana, Florence, Italy.
Prof. H. H. Giglioli, Museum Vertebrate Zoölogy, Florence, Italy.
Dr. Alberto Perngia, Museo Civico di Storia Naturale, Genoa, Italy.
Societa Italiana de Scienze Naturali, Milan, Italy.
Societa Africana d' Italia, Naples, Italy.
Dell 'Academia Pontifico de Nuovi Lincei, Rome, Italy.
Minister of Agriculture, Industry and Commerce, Rome, Italy.
Rassegna della Scienze Geologiche in Italia, Rome, Italy.
R. Comitato Geologico d' Italia, Rome, Italy.
Prof. Count. Tomasso Salvadori, Zoölog. Museum, Turin, Italy.

Royal Norwegian Society of Sciences. Throndhjem, Norway.
Dr. Robert Collett, Kongl. Frederiks Univ., Christiana, Norway.

Academia Real des Sciencias de Lisboa (Lisbon), Portugal.

Comité Geologique de Russie, St. Petersburg, Russia.
Imperial Academy of Sciences, St. Petersburg, Russia.
Imperial Society of Naturalists, Moscow, Russia.

The Botanical Society of Edinburgh. Edinburgh, Scotland.
John J. Dalgleish, Brankston Grange, Bogside Sta., Sterling, Scotland.
Edinburgh Geological Society, Edinburgh, Scotland.
Geological Society of Glasgow, Scotland.
John A. Harvie-Brown, Duniplace House, Larbert, Stirlingshire, Scotland.
Natural History Society, Glasgow, Scotland.
Philosophical Society of Glasgow, Glasgow, Scotland.
Royal Society of Edinburgh, Edinburgh, Scotland.
Royal Physical Society, Edinburgh, Scotland.

Barcelona Academia de Ciencias y Artes, Barcelona, Spain.
Royal Academy of Sciences, Madrid, Spain.
Institut Royal Geologique de Suède, Stockholm, Sweden.
Societé Entomologique à Stockholm, Stockholm, Sweden.
Royal Swedish Academy of Science, Stockholm, Sweden.

Naturforschende Gesellschaft, Basel, Switzerland.
Naturforschende Gesellschaft in Berne, Berne, Switzerland.
La Societé Botanique Suisse, Geneva, Switzerland.
Societé Helvetique de Sciences Naturelles, Geneva, Switzerland.
Societé de Physique et d' Historie Naturelle de Geneva, Geneva, Switzerland.
Concilium Bibliographicum, Zürich-Oberstrasse, Switzerland.
Naturforschende Gesellschaft, Zürich, Switzerland.
Schweizerische Botanische Gesellschaft, Zürich, Switzerland.
Prof. Herbert H. Field, Zürich, Switzerland.

AUSTRALIA.

Linnean Society of New South Wales, Sidney, New South Wales.
Royal Society of New South Wales, Sidney, New South Wales.
Prof. Liveridge, F. R. S., Sidney, New South Wales.
Hon. Minister of Mines, Sidney, New South Wales.
Mr. E. P. Ramsey, Sidney, New South Wales.
Royal Society of Queensland, Brisbane, Queensland.
Royal Society of South Australia, Adelaide, South Australia.
Victoria Pub. Library, Museum and Nat. Gallery, Melbourne, Victoria.
Prof. W. L. Buller, Wellington, New Zealand.

NORTH AMERICA.

Natural Hist. Society of British Columbia, Victoria, British Columbia.
Canadian Record of Science, Montreal, Canada.
McGill University, Montreal, Canada.
Natural Society, Montreal, Canada.
Natural History Society, St. Johns, New Brunswick.
Nova Scotia Institute of Science, Halifax, N. S.
Manitoba Historical and Scientific Society, Winnepeg, Manitoba.
Dr. T. McIlwraith, Cairnbrae, Hamilton, Ontario.
The Royal Society of Canada, Ottawa, Ontario.
Natural History Society, Toronto, Ontario.
Hamilton Association Library, Hamilton, Ontario.
Canadian Entomologist, Ottawa, Ontario.

Department of Marine and Fisheries, Ottawa, Ontario.
Ontario Agricultural College, Guelph, Ontario.
Canadian Institute, Toronto.
Ottawa Field Naturalists' Club, Ottawa, Ontario.
University of Toronto, Toronto.
Geological Survey of Canada, Ottawa, Ontario.
La Naturaliste Canadian, Chicontini, Quebec.
La Naturale Za, City of Mexico.
Mexican Society of Natural History, City of Mexico.
Museo Nacionale, City of Mexico.
Sociedad Cientifica Antonio Alzate, City of Mexico.
Sociedad Mexicana de Geographia y Estadistica de la Republica Mexicana, City of Mexico.

WEST INDIES.

Victoria Institute, Trinidad, British West Indies.
Museo Nacional, San Jose, Costa Rica, Central America.
Dr. Anastasia Alfaro, Secy. National Museum, San Jose, Costa Rica.
Rafael Arango, Havana, Cuba.
Jamaica Institute, Kingston, Jamaica, West Indies.

SOUTH AMERICA.

Argentina Historia Natural Florentine Amegline, Buenos Ayres, Argentine Republic.
Musée de la Plata, Argentine Republic.
Nacional Academia des Ciencias, Cordoba, Argentine Republic.
Sociedad Cientifica Argentina, Buenos Ayres.

Museo Nacional, Rio de Janeiro, Brazil.
Sociedad de Geographia, Rio de Janeiro, Brazil.
Dr. Herman von Jhering, Dir. Zoöl. Sec. Con. Geog. e Geol. de Sao Paulo. Rio Grande do Sul, Brazil.
W. J. Moenkhaus, Museu Paulista, Sao Paulo, Brazil.

Deutscher Wissenschaftlicher Verein in Santiago, Santiago, Chili.
Societé Scientifique du Chili, Santiago, Chili.
Sociedad Guatemalteca de Ciencias, Guatemala, Guatemala.

. . . PROGRAM . . .

OF THE

THIRTEENTH ANNUAL MEETING

OF THE

Indiana Academy of Science,

STATE HOUSE, INDIANAPOLIS,

December 29 and 30, 1897.

OFFICERS AND EX-OFFICIO EXECUTIVE COMMITTEE.

THOMAS GRAY, President, C. A. WALDO, Vice-President, JOHN S. WRIGHT, Secretary,
A. J. BIGNEY, Asst. Secretary, W. P. SHANNON, Treasurer.

STANLEY COULTER,	AMOS W. BUTLER,	W. A. NOYES,	J. C. ARTHUR,
J. L. CAMPBELL,	O. P. HAY.	T. C. MENDENHALL,	JOHN C. BRANNER,
J. P. D. JOHN,	JOHN M. COULTER,	DAVID S. JORDAN.	

The sessions of the Academy will be held in the State House in the rooms of the State Board of Agriculture.

Headquarters will be at the Bates House. A rate of $2.00 and up per day will be made to all persons who make it known at the time of registering that they are members of the Academy.

Reduced railroad rates for the members can not be obtained under the present rulings of the Traffic Association. Many of the colleges can secure special rates on the various roads. Those who can not do this could join the State Teachers' Association and thus secure the one and one-third round trip fare accorded to them.

W. P. SHANNON,
R. E. LYONS,
Committee.

GENERAL PROGRAM.

TUESDAY, DECEMBER 28.

Meeting of Executive Committee at the Hotel Headquarters .... 8 p. m.

WEDNESDAY, DECEMBER 29.

Gederal Session .... 9 a. m. to 12 m
Sectional Meetings .... 2 p. m. to 5 p. m.
Address by President Thomas Gray .... 7 p. m.

THURSDAY, DECEMBER 31.

General Session, followed by Sectional Meetings .... 9 a. m. to 12 m.
General Session .... 2 p. m. to 4 p. m.

LIST OF PAPERS TO BE READ.

ADDRESS BY THE RETIRING PRESIDENT,

PROFESSOR THOMAS GRAY,

At 7 o'clock Wednesday evening.

Subject: "The Development of Electrical Science."

The address has been placed at this early hour in order that other engagements for the usual hours of evening entertainment may not keep the members of the Academy and their friends from being present.

The following papers will be read in the order in which they appear on the program except that certain papers will be presented "*pari passu*" in sectional meetings. In order that the labor of presentation may be relieved, papers presented by the same authors have been separated, unless such separation would impair the value of the papers. When a paper is called and the reader is not present it will be dropped to the end of the list, unless by mutual agreement an exchange can be made with another whose time is approximately the same. Where no time was sent with the papers, they have been uniformly assigned ten minutes. Opportunity will be given after the reading of each paper for a brief discussion.

N. B.—By the order of the Academy, no paper can be read until an abstract of its contents or the written paper has been placed in the hands of the Secretary.

GENERAL SUBJECTS.

1. Lake Maxinkuckee soundings, 12 m.................J. T. Scovell.
2. Photometric measurements of different samples of oil, 5 m.. C. T. Knipp.
3. Pure yeast in bread, 10 m.................Miss Katherine Golden.
4. A new laboratory and its work, 6 m...............Robert Hessler.
5. A case of microcephaly ,10 m.....................D. W. Dennis.
6. The relation of geography to natural science and education, 15 m...C. R. Dryer.
7. The Academy as a possible factor in the biological instruction in our secondary schools, 10 m................L. J. Rettger.
8. Susceptibility of different starches to digestive ferments, 15 m...W. E. Stone.
9. A new apparatus for photomicroscopy, 10 m..........A. W. Bitting. Illustrated by photographs.

MATHEMATICAL AND PHYSICAL SUBJECTS.

10. An infinite system of forms, satisfying the requirements of Hilbert's Law, 10 m...J. A. Miller.
11. Decrease of intensity of shrill sounds with time, 15 m..A. W. Duff.
12. The constant radiation of air, 5 m.....................A. W. Duff
13. Preliminary results with an apparatus for the study of impact, 15 m......................A. W. Duff and J. B. Meyer.
14. Variations on the spectrum of the open and closed electric arc, 15 m...A. L. Foley
15. The spectrum of cyanogen, 10 m......................A. L. Foley.
16. The electrolytic nature of the electric arc, 15 m........A. L. Foley.
17. Note on Charles Smith's definition of multiplication, 2 m..R. J. Aley.
18. Collinear sets of three points connected with the triangle, 15 m..R. J. Aley.
*19. Note on the theorem of Magnus concerning the relation of linear transformation to projection, 10 m..........S. C. Davisson.
20. On the reduction of irrational algebraic integrals, 10 m..J. B. Faught.
*21. Three proofs of the proposition—"The tangents to a point conic are lines of a line conic," 15 m.............U. S. Hanna.
*22. Some tests on ball bearings, 10 m....................M. J. Golden.
23. Alternate processes, 15 m.........................A. S. Hathaway.
24. A new form of galvanometer, 10 m................J. Henry Lendi.
25. A relation between elastic limit in flexure and tension..W. K. Hatt.
26. Behavior of wrought iron under compression..........W. K. Hatt.

CHEMICAL AND BACTERIOLOGICAL SUBJECTS.

27. Camphoric acid, 15 m..............................W. A. Noyes.
28. Certain combustion products of natural gas, 5 m......P. N. Evans.
*29. The melting point of cane-sugar, 5 m.................W. H. Test.
30. Nitro derivatives of low-boiling paraffines, 5 m......R. G. Worstall.
31. Occurrence of nitrogen in gases derived from bacterial fermentation, 5 m....................S. Burrage and A. H. Bryan.
32. Micro-organisms in flour, 10 m.......................C. G. Ferris.
33. The number of colonies of bacteria and moulds obtained in the testing of air, milk and water by different culture media, 10 m.................................A. W. Bitting.

*34. Concerning the alkaloids of Lupinus subcarnosis, 10 m..L. S. Davis.

*35. Notes on selanthren, 5 m.................................R. Lyons.

*36. The synthesis of a new member of the furan-thiophen group, 10 m............................R. Lyons and H. Reddick.

BOTANICAL SUBJECTS.

37. The effects of formalin on germinating seeds, 8 m...M. B. Thomas.

38. The Myxomycetes of Crawfordsville, 10 m............E. W. Olive.

39. The germ of pear-blight, 15 m................Miss Lillian Snyder.

40. Water power for botanical apparatus, 10 m..........J. C. Arthur.

*41. Development of the embryo-sac of Solea concolor, 10 m. F. M. Andrews.

42. Contributions to the flora of Indiana, No. V., 10 m..Stanley Coulter.

43. Notes concerning the germination of composites, 10 m. Stanley Coulter.

*44. The Mycorrhizae of Aplectrum, 10 m............D. T. Mac Dougal.

*45. The tendrils of Eutada scandens, 5 m............D. T. Mac Dougal.

46. Distribution of the Ericaceæ in Indiana, 10 m..Alida Cunningham.

47. Distribution of the Gentianaceæ in Indiana, 10 m. Alida Cunningham.

48. Inarching of oak trees..............................John S. Wright.

49. Notes on the cypress swamps of Knox county, Indiana. John S. Wright.

ZOOLOGICAL SUBJECTS.

50. Some Indiana crow roosts, 10 m......................A. W. Butler.

51. Notes on crow roosts of Western Indiana and Eastern Illinois. John S. Wright.

52. Brunnich's Guillemot (Uria lomvia) an addition to the birds of Indiana, 10 m.................................A. W. Butler.

53. Notes on the birds observed in the vicinity of Wayne county, Indiana, 10 m..............................Alden H. Hadley.

54. Notes on Indiana heronries, 10 m....................A. W. Butler.

55. The recent occurrence of the raven in Indiana, 10 m..A. W. Butler.

56. A description of new facial muscles in the Anura, with new observations on the nasal muscles of salamanders, 20 m. H. L. Bruner.

57. A rare species of Bascarion (B. ornatum), 6 m........H. L. Bruner.

58. Structure of the heart of lungless salamanders, 10 m..H. L. Bruner.
59. The pulmonary arch of lungless salamanders, 12 m..Miss MacWoldt.
*60. Methods of staining to show centrosomes in egg cells. (Illustrations), 12 m....................................L. J. Rettger.
61. An instance of bird ferocity, 2 m..................G. Culbertson.
*62. A revision of the genus Io, 10 m.......................R. E. Call.
63. Material for the study of variation in Etheostoma caprodes, 15 m......................................J. N. Moenkhaus.
64. Origin of cave fauna, 15 m......................C. H. Eigenmann.
65. The eyes of the Amblyopsidae, 15 m............C. H. Eigenmann.
66. A new species of blind fishes from the caves of Missouri, 5 m.................................... C. H. Eigenmann.
67. The habits of Amblyopsis, 15 m..................C. H. Eigenmann.
68. The blind salamanders of North America, with specimens, 5 m..C. H. Eigenmann.
69. Embryology of Paragordius (Gordius) aquaticus........A. B. Ulrey.

GEOLOGICAL SUBJECTS.

70. Formation of quicksand pockets in the blue clay of South Bend, 10 m...................................W. M. Whitten.
71. The Cady marsh, 8 m...............................F. H. Ball.
72. Preliminary work for the approximate determination of the time since the retreat of the first great ice sheet, 8 m. G. Culbertson.
73. Note on fault structure in Indiana..............George H. Ashley.
*74. Notes on the geology of Mammoth Cave, 10 m...........R. E. Call.
75. A section from Hanover to Vincennes, 10 m........J. F. Newsom.
76. The Knobstone groups in the region of New Albany, 10 m. J. F. Newsom.
77. The upper limits of the Knobstone in the region of Borden, 8 m...L. H. Jones.
78. Four sections across the Knobstone group, 15 m....L. F. Bennett.
79. Notes on Indiana geology, 10 m........................J. A. Price.
80. An old river channel in Spencer county, 15 m..........A. C. Veatch.

*Author absent; paper not presented.

THIRTEENTH ANNUAL MEETING OF THE INDIANA ACADEMY OF SCIENCE.

The thirteenth annual meeting of the Indiana Academy of Science was held in Indianapolis, Wednesday and Thursday, December 29th and 30th, 1897, preceded by a session of the Executive Committee of the Academy, 8 p. m., Tuesday, December 29th.

At 9 a. m., December 29th, President Thomas Gray called the Academy to order in general session, at which committees were appointed and much other routine and miscellaneous business transacted. After the disposition of these affairs the reading and discussion of papers of the printed program, under the title of "General Subjects" occupied the time until adjournment at 12 m.

The Academy met at 2 p. m. in two sections, biological and physico-chemical, for the reading and discussion of papers. President Thomas Gray presided over the physico-chemical section and Vice-President C. A. Waldo over the biological section. At 5 p. m. the section meeting adjourned to meet in general session of the Academy at 7 p. m.

The Executive Committee met at 5:30 p. m., holding a brief business session.

Academy met 2 p. m. Following the disposition of committee reports and the transaction of other business the retiring president, Dr. Thomas Gray addressed the Academy on "The Development of Electrical Science."

Thursday, December 30th, 9:20 a. m., the Academy met in general session for the transaction of business, after which it divided into sections for the consideration of papers. President Gray acted as chairman of the physico-chemical section, Vice-President Waldo presided over the biological.

Adjournment of physico-chemical section, 10:20 a. m.

Adjournment of biological section, 12:15 p. m.

THE FIELD MEETING OF 1897.

The Field meeting of 1897 was held Thursday and Friday, May 27th and 28th at Lafayette, Indiana. On the evening of the 28th the executive committee of the Academy met and transacted miscellaneous business.

Thursday morning, May 27th, the members started into the field, going by conveyance into the vicinity of Battle Ground, where they divided into sections for special work. At noon all met at Tecumseh's Trail, where luncheon was served, after which the Academy visited the State Soldiers' Home. On the return to the city the country home of Mr. Mortimer Levering was visited, where a reception was given to the members.

Thursday evening, at 8 p. m., the Academy met in the chapel of Purdue University and was addressed by Dr. Frederick Starr on "Dress and Adornment." Following the lecture a short business session was held.

Friday morning, May 28th, the members visited the laboratories of Purdue University, after which they took conveyances and drove to the site of Fort Ouiatenon, where special field work was done.

The Academy is greatly indebted to the Lafayette members and their friends, whose energy and generosity made the field meeting of 1897 a marked success.

PRESIDENT'S ADDRESS.

THE DEVELOPMENT OF ELECTRICAL SCIENCE.

BY THOMAS GRAY.

In a brief discourse on the development of electrical science, little time can be given to the early history of the subject. This part is more or less familiar to all the members of the academy, and hence it may be passed over by only such brief reference as may serve to recall to mind the more important of the early discoveries. The early Greeks have recorded some elementary phenomena now known to be electric, and it is probable that such knowledge was not uncommon, though little noticed. It is only in comparatively recent times that scientific research has taken the place of superstition, and attempts have been made to classify and find reasons for the existence of all natural phenomena.

Beginning with the seventeenth century, probably the first investigator worthy of notice in this subject was Gilbert of Colchester, who published his work entitled "De Magnete" in 1600. Gilbert made systematic experiments and showed that the property of attracting light bodies could be given to a large number of substances by friction. He also showed that the success of the experiment depended largely upon the dryness of the body. These experiments gave rise to the classification of substances as electrics and non-electrics. The true effect of Gilbert's observations as to the effect of moisture was not appreciated for a long time. Gilbert's list of electrics was added to by a number of other observers, prominent among whom was Boyle and Newton. The fact that light and sound accompanies electric excitation was called attention to by Otto Von Guericke, who also showed that a light body, after being brought into contact with an electrified body, was repelled by it.

Coming now to the eighteenth century, we find Hawkesbee in 1707, and Wall in 1708, speculating on the similarity of the electric spark and lightning. Then comes one of the most prominent experimenters of this century—Stephen Gray—who began to publish in 1720, and who in 1729 found that certain substances would, and others would not, convey the charge of an electrified body to a distance. These experiments were the first to introduce the distinction between conductors and non-conductors, and, of course, very soon served to explain the reason why certain substances could not be electrified by friction when held in the hand. Gray also made the important discovery that the charge of an electrified body is proportional to its surface, and this was afterward confirmed by the experiments of Le Monnier. Many of Gray's experiments were repeated and extended by DuFay, who found that all bodies could be electrified by friction if they were held by an insulating substance. Then came the improvements of the electric machine by Boze and Winckler; the firing of inflammatory substances, such as alcohol, by means of the electric spark by Ludolph, Gordon, Miles, Franklin, and others. About this time (1745) the properties of the Leyden jar were discovered by Kleist, Cuneus, and Muschenbroeck; and a few years later it was given practically its present form by Sir William Watson. Then follows one of the periods of exceptional activity in electrical research. A party of the Royal Society, with Watson as chief operator, made a series of experiments having for their object the determination of the distance to which electrical excitation could be conveyed and the time it takes in transit. They found, among other things, that several persons at a distance apart might feel the electric shock if they formed part of a circuit between the electrified body and a conductor, such as the earth. Also, that the earth could be used to complete the circuit in Leyden jar discharges. They concluded that when two observers connected by a conductor and at, say, two miles apart, obtained a shock by one touching the inside coating of a Leyden jar and the other the earth, the electric circuit was four miles long; that is, the earth acted as a return conductor. They also concluded that the transmission was practically instantaneous. Watson had ideas as to electric fluids similar to those which were afterward systematically worked out by Franklin. A great many curious and interesting experiments were made about this time; as, for example, the influence of electrification on the flow of water through capillary tubes as discovered by Boze; the experiments of Mowbray on the effect of electrification on vegetation, and those of the Abbe Monon on the loss of weight of animals when they were kept electrified for a considerable time. The effect of electrification on the flow of water has received considerable attention from eminent authorities in recent years, and that of the effect of electrification on the growth and composition of vegetables is at present attracting attention in the form of systematic investigation.

The contributions by Franklin are by far the most important which mark the middle portion, or indeed any portion, of the eighteenth century.

Franklin's experiments were begun about the beginning of the year 1747, and seem to have been inspired by the receipt of a Leyden jar from a friend, Mr. Collinson, of London. He propounded the theory of positive and negative fluids, which has lately, in a modified form, been brought so prominently into notice by the writings of Lodge; and he made an investigation of the principle of the Leyden jar, but the most important of his researches relate to the identification of electricity and lightning. The probable identity of the two phenomena had been hinted at, as we have seen, by several observers, but Franklin went systematically to work to test the hypothesis. Under date November 7th, 1749, the following passage is found in his note book:

"Electric fluid agrees with lightning in these particulars: (1) Giving light; (2) Color of light; (3) Crooked direction; (4) Swift motion; (5) Being conducted by metals; (6) Crack or noise in exploding; (7) Subsisting in water or ice; (8) Bending bodies in passing through; (9) Destroying animals; (10) Melting metals; (11) Firing inflammable substances; (12) Sulphurous smell. The electric fluid is attracted by points; we do not know whether this property is in lightning, but since they agree in all the particulars wherein we can already compare them, is it not probable they agree likewise in this? Let the experiment be made."

The hypothesis was elaborated and sent to his friend Collinson, who communicated it to the Royal Society. This Society rather ridiculed Franklin's idea at first, but his paper was published in London and also in France, and attracted considerable attention.

The experiment was first made in France by M. d'Alibard, at Marle, on May 10th, 1752, and repeated shortly afterward by M. de Lor, in Paris. The results of what were called the Philadelphia experiments were communicated to the Royal Society and caused quite a stir in scientific circles. It is right to say with regard to the Royal Society, that Franklin's claims to scientific recognition were championed by Sir William Watson and were fully indorsed by the Society by Franklin's election to fellowship and the award of the Copley Medal, together with the free donation of the Society's transactions during his life.

Franklin's own experiments with kites are well known, as is also the method of protecting buildings from lightning, which was introduced by him and is still very widely used, although it has been greatly abused by the lightning-rod man.

During the next decade Canton discovered the now commonly known difference between vitreous and resinous electricity. Beccaria experimented on the conducting power of water. Symmer made a number of experiments on the electrification of different kinds of fabrics by friction, and propounded a theory of two electric fluids. Contemporaneous with these were a number of other experimenters who added to the stock of knowledge of this class of phenomena.

The experiments of Aepinus and others on the pyroelectric properties of tourmaline now began to attract attention. The experiments of the Abbe Haüy are perhaps the most important in this connection at this stage of the subject. He found the polar properties of the crystal and showed that similar properties are possessed by a number of other crystals. Aepinus made experiments in other branches of electricity, but he is chiefly noted for his ingenious single fluid theory of electricity.

Between the years 1770 and 1780, the electric organs of the torpedo was one of the principal topics of discussion. The experiments of Walsh and Ingenhousz were the first to settle definitely the character of the peculiar power of the fish.

The experiments of Cavendish belong to this period and were remarkable as being quantitative in their character. Considering the means at his command, the measurements made by this experimenter of the relative conducting powers of various substances must always excite admiration. Cavendish also proved the composition of water by causing different proportions of oxygen and hydrogen to unite by means of the electric spark.

We now come to the classical experiments of Coulomb, who established the law of the variation of the electric force with distance to be that of the inverse square: a law which had previously been inferred from experiments on spheres by Dr. Robinson, who, however, did not publish his results. Coulomb made an elaborate series of experiments on the distribution of electricity over charged conductors as influenced by shape and the proximity of other charged bodies. His theoretical and experimental work formed the basis of the mathematical theory as developed shortly afterwards by Laplace, Biot, and Poisson; the work of the latter being particularly important.

Toward the end of the eighteenth century were made the important researches of Laplace, Lavoisier, and Volta, and of Sausure on the electricity produced by evaporation and combustion. This is a subject destined to figure prominently again in the future; and in its rise there is in all probability involved the rapid decline in the importance of the steam engine. I should not be surprised if many of those present should live to see the steam engine practically a thing of the past. To the eighteenth century also we must assign the discovery of galvanic electricity, as the famous frog experiments were made in 1790; practically, however, no development was made until Volta's work attracted the attention of the scientific world. At the beginning of the nineteenth century, then, we find the subjects of greatest interest were the discoveries of Volta and the invention of the voltaic pile. Then followed almost immediately the discovery of Nicholson and Carlisle of the decomposition of water by the voltaic current. This discovery was followed a few years later by the discovery of Sir Humphrey Davy of the decomposition of the alkalies and the separation of metallic sodium and potassium. Thus the subject of electrolysis was fairly launched, and what it has grown to we will see later.

Can there be some inter-relation between electricity and magnetism was now the query. The first positive answer seems to have been given by Romagnesi in a work published in 1805, but little or no notice appears to have been taken of this; certainly no progress was made in the subject till 1820, when Oersted made his famous experiment before his class. By that experiment he proved that a wire carrying an electric current will, when properly placed, deflect a magnetic needle. The subject was almost immediately taken up by Ampere, and in a few months many of the important consequences which Oersted's discovery involved were developed. Ampere's work on the action of currents on currents and on magnets, is classical and is still treated as part of the fundamental basis for the theory of electro-dynamics. An account of his work may therefore be found in almost any of the numerous text-books on electricity. The conclusions reached by Ampere were confirmed by Weber, by a series of much more refined experiments. To Weber also we owe improvements in galvanometers. The same year marks the discovery by Arago that a current can not only deflect a magnet, but that it is capable of producing one by magnetizing steel needles. The further discovery was made four years later by Sturgeon that soft iron, although incapable of making a strong permanent magnet, is much more susceptible to magnetization by the electric current. Arago also made about this time the important discovery that if a needle be suspended above a copper disc and the disc rotated, the needle will be dragged round with the disc. This was not explained for some years, but seems to have been the first discovery of induced currents.

These experiments mark the discovery of electro-magnetism and begin one of the most important eras in electrical discovery, and one in which many eminent authorities participated. Among the many advances may be mentioned the experiments by Henry on the relative effects of different windings on the strength of an electro-magnet. He deduced the fact that the magnetizing action might be increased either by increasing the number of windings, the current remaining the same; or by increasing the current, the windings remaining the same. He pointed out the application of this to intensity and quantity arrangement of the battery, and also the importance of the intensity winding for the transmission of magnetizing power to a distance, as in telegraphy. The increased effect due to increasing the number of windings on the coil of a galvanoscope had been previously pointed out by Schweigger, and the discovery is embodied in Schweigger's galvanoscope.

In 1821, Faraday began his researches and many important discoveries were made by him. The main guiding idea in Faraday's work was the possibility of obtaining electricity from magnetism, and in general the discovery of the inter-relation between the two. In this connection, Arago s discovery of the rotation of a copper disc by the rotation of a magnet above it is of great importance, because among other things Faraday set himself to explain this. The result was the discovery of the commutatorless dynamo or Faraday disc. In view of modern developments, probably the most important of Faraday's discoveries was that of the production of a current in a circuit when a current is either established or varied in strength in an adjacent circuit. This was followed by the discovery that relative motion of two circuits, one of which carried a current, poduced a current in the other, and that the motion of a magnet in the neighborhood of a circuit produced a current in the circuit. Another important discovery by Faraday was that of the quantitative laws which govern electrolytic decomposition, thus giving us our electro-chemical equivalents.

At this time Lenz was led by experiment to the discovery of his celebrated law of induction, namely, that the current produced always in turn produces forces tending to oppose the change. For example, if a current be induced in a coil by bringing a magnet toward it, the mutual action between the magnet and the current is to oppose the magnet's approach. This is important when looked at from the point of view of the conservation of energy, or as an argument against perpetual motion. Lenz's law is, of course, when the actions are properly understood, a consequence of Newton's third law of motion.

Discoveries similar to those of Faraday as to induced currents were made almost simultaneously by Henry in this country. We have in the discoveries of Faraday and Henry the fundamental information required for nearly the whole of our recent developments in dynamo-electric generators and electric motors, but it was reserved for the next generation to develop them. This development we owe in no small degree to the splendid exposition of Faraday's discoveries and their consequences, contained in Maxwell's book on electricity and magnetism.

Going back for a minute to 1822, we have to notice another important discovery; namely, the thermo-electric couple by Seebeck. There followed almost immediately the important experiments of Cumming, who showed that the thermo-electric order of the metals is not the same at all temperatures. The next important discovery in thermo-electricity was that by Peltier of the heat generated at the junction of two metals when a current is formed across it against the e. m. f. of the junction. In later years we have the classic researches of Thomson (Kelvin), who added thermo-electric convection and the specific heat of electricity, and gave the thermo-electric diagram method of representing results. This method was afterward used and extended by Tait, who added a good deal to our knowledge of thermo-electric data. Among the large number of others who have worked in this field, we may mention Becquerel, Magnus, Matthieson, Leroux, and Avenarius. Thermo-electric batteries of considerable power have been made by Clamond and others.

In 1827 the celebrated law giving the relation between e. m. f. resistance and current was published by Ohm in a paper on the mathematical theory of the Galvanic circuit. The theory has been sometimes criticised, but it seems to be absolutely certain that the law is almost exact, and it has proved to be of the greatest importance in the further development of the subject of electric measurements. The subject had, about the middle of the century, reached a stage in which it was possible to develop almost completely the mathematical theory as we now have it. Most of the work since Faraday's time has been largely directed toward quantitative measurements and the furnishing of exact data to answer questions as to *how much* in various cases. F. E. Neumann discovered what he called the potential function (now called the coefficient of self and mutual induction) of one current on another and on itself, and succeeded in giving a theory of induction which was in accordance with the experimental laws. The laws were afterward experimentally verified by Weber. In 1849 the experiments of Kirchhoff on the absolute value of the current induced in circuit by another, and in the same year Edmund's experiments on self and mutual induction, are important. In 1851 Helmholtz gave a mathematical theory of this part of the subject which he supplemented with an experimental verification.

One of the most important of the series of experiments made by Henry was on the oscillatory character of the discharge from a Leyden jar. This he discovered from the effect of the discharge on a steel needle surrounded by a coil through which the current was made to pass. The results of these experiments were communicated to the A. A. A. S. in 1850, but he knew of the effect much earlier, certainly in 1842. Previously the anomalous behavior of the discharge of a jar when used to magnetize steel needles had been noticed, but was attributed, I believe, to some peculiarity of the steel. Henry was the first to appreciate the true reason, although he could hardly at that time be expected to see the great importance of his discovery.

Helmholtz in 1847 suggests that the discharge of Leyden jars may be of the nature of a backward and forward movement. There is a curious parallelism in the work of several investigators about this time, and particularly in that of Helmholtz and Thomson. In the Philosophical Magazine for 1855 there is a paper by Prof. W. Thomson (Kelvin) in which the theory of the discharge of a Leyden jar is discussed and the prediction made that under certain specified conditions the discharge must be oscillatory. A number of similar papers going back to 1848 treat of similar subjects. Henry's results do not appear to have become generally known, and we find the verification of Thomson's prediction in 1857 by Feddersen. A number of other physicists have investigated the subject, the work of Schiller being of particular value. The recent applications will be referred to later.

The mathematical theory of electrostatics and magnetism was greatly extended about this time by Thomson and others, and received its most complete statement at the hands of Maxwell in his papers read before the Royal Society and in his book published in 1873, still the standard of reference. Very little has since been discovered which was not foreshadowed by Maxwell's theory or contained in his equations which have been found general enough to cover almost everything, although experiment has generally been necessary to suggest the consequences of the theory.

The practical applications of electricity have played a most important part in the development of the subject in the last sixty years. Indeed, a great part of the work of these years has had some practical application in view. One of the first of these practical applications was that of telegraphy. The telegraph, being one of the earliest of the practical developments, naturally had a great effect in stimulating the advance in knowledge of electricity, and hence I give a somewhat fuller sketch of the early history than space will permit for the later applications. The discovery of Stephen Gray in 1729, that the electrical influence could be conveyed to a distance by means of an insulated wire, is probably the first discovery of direct influence in connection with telegraphy. As a result of this discovery and the investigations which followed it, a considerable number of proposals were made as to the use of the electrical force for the transmission of intelligence. The first of these of which I have found any record was made in 1737 by Charles Morrison, a Scotchman, and there followed other proposals for electrostatic telegraphs by Bozolus in 1767, Le Sage in 1774, Lomond in 1787, by Betancourt in the same year, by Reizen in 1794, Cavallo in 1795, and by Ronolds in 1816.

The discovery of voltaic electricity, and most directly the discovery by Nicholson and Carlisle of electrolysis, gave rise to another group of proposals for the application of this discovery to the production of a telegraph. Among those may be mentioned that of Sömmering in 1809, of Coxe in 1810, and of Sharpe in 1813. In more recent years of course the same application appears in the chemical telegraphs, some of which are capable of giving very satisfactory results and great speed.

The discovery which had the greatest influence on the development of telegraphy was that of Oersted, supplemented by the work of Schweigger and Ampere. Ampere proposed a multiple-wire telegraph with galvanoscope indicators in 1820, and a modification was constructed by Ritchie. A single circuit telegraph of this character was invented in 1828 by Tribaoillet, but did not come into use. In 1832 Schilling's five-needle telegraph appeared, and he also used a single-needle instrument; but his early death stopped further progress. In 1833 Schilling's telegraph was developed to some extent by Gauss and Weber, who used it for experimental purposes. The following quotation referring to Gauss and Weber's telegraph, from Poggendorf's Annalen, is of considerable historical interest:

"There is, in connection with these arrangements, a great, and until now in its way novel, project, for which we are indebted to Professor Weber. This gentleman erected during the past year a double-wire line over the houses of the town (Gottingen) from the Physical Cabinet to the Observatory, and lately a continuation from the latter building to the Magnetic Observatory. Thus an immense galvanic chain is formed, in which the galvanic current, the two multipliers at the ends being included, has to travel a distance of nearly 9,000 (Prussian) feet. The line wire is mostly of copper of that known as 'No. 3,' of which one meter weighs eight grammes. The wire of the multipliers in the magnetic observatory of copper 'No. 14,' silvered, of which one meter weighs 2.6 grammes. This arrangement promises to offer opportunities for a number of interesting experiments. We regard, not without admiration, how a single pair of plates, brought into contact at the further end, instantaneously communicates a movement to the magnetic bar, which is deflected at once for over a thousand divisions of the scale." Further on in the same paper: "The ease with which the manipulator has the magnetic needle in his command, by means of the communicator, had a year ago suggested experiments of an application to telegraphic signaling, which, with whole words and even short sentences, completely succeeded. There is no doubt that it would be possible to arrange an uninterrupted telegraph communication in the same way between two places at a considerable number of miles distance from each other."

The method of producing the currents in Gauss and Weber's experiments was an application of the important discoveries of Faraday and Henry above referred to, in the induction of current by currents and by magnets. On the recommendation of Gauss the telegraph was taken up by Steinheil who, following their example, also used induced currents. The important contributions of Steinheil were the discovery of the earth return circuit, the invention of a telegraphic alphabet and a recording telegraph. Steinheil contributes an account of his telegraph to Sturgeon's Annals of Electricity, in which the relative merits of scopic, recording, and acoustic telegraphs are discussed; and the advantages, which experience has since brought into prominence, of the acoustic form is pointed out.

Schilling's telegraph was exhibited at a meeting of German naturalists held at Bonn in 1835, and was there seen by Prof. Muncke of Heidelberg, who, after his return to Heidelberg, made models of the telegraph and exhibited them in his class room. These models were seen by Cooke in the early part of 1836, and gave him the idea of introducing the electric telegraph in England. Cooke afterward became associated with Wheatstone, and a large number of ingenious arrangements for telegraphing was the result. Many of the later developments by Wheatstone are still in use and are hard to beat.

Steinheil appears to have been anticipated in the idea of making the telegraph self-recording by Morse, who, according to evidence brought forward by himself, thought out some arrangements as early as 1832. Exactly what Morse's first ideas were seems somewhat doubtful, and he did nothing till 1835, when he made a rough model of an electro-magnetic recording telegraph. Morse's mechanical arrangements were of little merit and his alphabet and method of interpretation by a dictionary was clumsy and inconvenient. The chief point of interest in connection with the early history of the Morse telegraph was the proposal to make use of Sturgeon's discovery of electro-magnetism of soft iron. Morse, however, seems to have known practically nothing of the subject except that iron could be magnetized by a current, and in consulting his colleague, Dr. Gale, he was unwittingly led to use the discoveries of Henry who had previously practically solved the whole problem. Much of the subsequent improvements in the mechancial arrangements were due to Vail, who became associated with Morse, and the Morse code as we now know it was almost, if not entirely, worked out by Vail. Considerable dispute and some litigation arose over Morse's claims, but that is outside our present subject. There is no doubt that the electric telegraph was a slow growth, inventors, with a view to pecuniary and other advantage, being ever ready to lay hold of each scientific discovery and try to turn it to account. The question, who first conceived the idea, can never be satisfactorily answered. After 1840 there is little to record of a purely electrical character bearing only on telegraphy, but there have been many very ingenious mechanical contrivances introduced for recording signals, for reproducing pictures and handwriting, and for printing, for duplexing, quadruplexing, and multiplexing telegraph lines, for increasing the rate of signaling, and in many ways increasing the expedition with which messages can be sent. Of course the success of many of these contrivances and even their invention depended on increased knowledge of the laws of electricity and magnetism. For example, effective duplexing, quadruplexing, etc., depends on a proper understanding of the effect of the electrostatic capacity of the line, and this was not understood properly until the mathematical investigations of Thomson and others cleared the matter up. For the impetus toward discovery in this direction, again, we are largely indebted to telegraphy, for much of that class of work was suggested by the difficulties encountered in signaling through long submarine cables.

The invention of the telephone is fast becoming ancient history, yet it will always mark one of the greatest of the useful applications of electricity. It does not call for more than a passing remark here, because electro-magnetically it is all in Faraday and Henry's papers. The radiophone should be mentioned because it marks the application of the discovery by May and Smith of the effect of light on the resistance of selenium. This effect has since been found in the case of a large number of other substances, but it is still an interesting field for research. A number of experiments on this subject have been associated with attempts to make things visible at a distance. No doubt it will ultimately be possible not only to talk to a distant party, but also to see the party talked to, and thus, as it were, look the party in the eye with whom you are conversing.

The subject of telegraphy is closely associated with the present excellent system of electrical measurements and with the invention of many of our most delicate measuring instruments. As the applications of electricity increased there gradually grew up a new branch of engineering, a branch, however, in which the foot rule, pound weight, chronometer and thermometer were not sufficient. Other standards of measurement were required in order that quantities could be gauged and consistent work done. The way to connect the measurement of the new quantities with the units already in use in dynamics had been pointed out by Gauss and others, and at the suggestion of Thomson the British Association appointed a committee in 1861 to determine the best standard of electrical resistance. This led to an unexpected amount of work, not only on a standard of resistance, but also on the general subject of electrical measurements. The committee regretted at the end of the first year that it could not give a final report, but hoped that the inherent difficulty and importance of the subject would sufficiently account for the delay. It can hardly be said that the final report has yet been forthcoming, as a committee with some of the original members in it still exists and reports regularly every year on valuable work done by it. The committee worked energetically for a number of years, not only on the standard of resistance, but on those of current, electro-motive force and capacity. It incidentally supplied a great deal of quantitative data on a number of subjects and particularly as to the permanency of alloys, the variation of their resistance with temperature as depending on their composition, and so forth. In looking over the results of the early work of the British Association committee one is apt to indulge in adverse criticism. It is hard for many of the younger workers to appreciate the difficulties which are met in a first attempt. It would be equally just to congratulate ourselves that we have better marksmen to-day than there were fifty years ago, without making allowance for the modern rifle.

The first absolute determination of resistance was probably that made by Kirchhoff about fifty years ago. Weber published his method in 1852, and then came the British Association's determination by Maxwell, Stewart and Jenkin in 1863. Neither of these were very exact, but they paved the way for the splendid exhibitions of experimental skill which followed. Among those to whom we are most indebted for this later work may be mentioned Kohlrausch, Rayleigh, Glazebrook, Rowland, Wiedemann, Mascart, etc. The greatest step in advance in recent years has been the invention of the revolving disc method by Lorenz of Copenhagen, and its subsequent improvement and application by himself and by J. V. Jones. The determinations made by the latter by this method are probably almost absolutely correct.

A subject which has attracted much attention comes in incidentally here, namely, the electro-magnetic theory of light propagation suggested by Maxwell. According to this theory the ratio of the electro-magnetic unit of quantity of electricity to the electrostatic unit ought to be the same as the velocity of light. In 1868 a determination of this ratio was made by McKichan under Lord Kelvin's direction and gave close agreement with the theory. Since that time determinations have been made by various methods by Maxwell, Shida, Ayrton and Perry, J. J. Thomson, Rosa, Lodge, Glazebrook and others, with the result that the ratio of the two units does not differ from the velocity of light by as much as the probable error of observation. The work here referred to may not appear to be very directly associated with the determination of standards of measurement. It is, however, one of the investigations which has been made possible by the work of the British Association committee in the production of instruments of precision. Prominent among these instruments stands the Kelvin electrometers and particularly the absolute electrometer which was described in the report of the British Association committee in 1867.

Another subject of great interest in itself and in connection with Maxwell's theory is that of the specific inductive capacity of dielectrics. Experiments on this subject were made by Faraday, but comparatively little was done before 1870, in which year an excellent paper was communicated to the Royal Society by Gibson and Barclay on the specific inductive capacity of paraffin. Since that time much good work has been done by Boltzmann, Hopkinson, Quincke, Silow, Klemencic, Negreano and others. The theoretical importance of these experiments is due to the fact that according to Maxwell's theory the specific inductive capacity of nonmagnetic dielectrics should be proportional to the squares of their indices of refraction. A wonderful verification of Maxwell's theory was carried out only some ten years ago by Hertz, who showed not only that electrical waves exist, but also how to measure their wave length and period. We have in these experiments splendid illustrations of the oscillatory discharge referred to above as discovered by Henry and predicted by Thomson, and as a result several new ways of determining electrical quantities have been developed. It is now possible, for example, to compare the capacity of condensers by means of oscillatory currents of exceedingly short period and thus to determine the dielectric constants of many materials to which the older methods were not easily applicable.

It is somewhat difficult to decide where to place a reference to the recent discovery of Röntgen and its developments in photography, but probably it comes in well here. Just how to apply Maxwell's equations to Röntgen's rays is not yet quite clear, but there is no doubt as to the great importance of the discovery.

As an outcome of all this activity in the determination of standards and in the absolute measurement of the electric properties of materials, combined with the great commercial demand produced by the introduction of dynamo machinery, we have now many excellent instruments at our disposal for absolute measurement and suitable either for practical applications or for the most refined laboratory work. For the production of these we are indebted to a host of inventors. Prominent among them may be mentioned Lord Kelvin, Lord Rayleigh, Ayrton and Perry, Mather, Swinburne, Cardew and Weston.

Magneto-electric and dynamo-electric generators and motors have now become so common that we are apt to forget that their introduction on an extensive scale has only taken a few years. Faraday's disc dynamo was, as has already been stated, produced in 1831, and a machine for generating electricity was made by Pixii in the following year. Pixii's machine consisted of a horseshoe permanent magnet, which was rotated in such a way that its poles passed alternately in front of the poles of a similar electro-magnet. An alternating current was thus induced in the circuit which included the coils of the electro-magnet. This machine was improved by Clarke, who revolved the coils and put a commutator on the axle. Other machines were made or suggested by various physicists, and an important observation, which has since been frequently overlooked, was made at this time by Jacobi, who pointed out the importance of making the cores of the coil short. Sturgeon in 1835 made a dynamo with a shuttle-shaped armature; a similar form has long been identified with the name of Siemens. Woolrich made a multipolar magneto machine in 1841 for electroplating, and Wheatstone about this time produced his small multipolar magneto long used for telegraph purposes. In 1845 Wheatstone and Cooke patented the use of electro-magnets in place of the permanent magnets, and Brett suggested in 1848 that the current from the machine might be made to pass round a coil surrounding the magnet and thus increase its strength. A similar suggestion was independently made in 1851 by Sinsteden. In 1849 Pulvermacher proposed the use of thin laminae of iron for the cores of the magnet, a proposition which has since, but probably for a different reason, been almost universally adopted. Sinsteden used iron wire cores and made a number of experiments on the effect of varying the pole face. About this time another class of machines was proposed by Ritchie, Page and Dujardin. In these machines both the magnets and the coils were to be stationary, but the magnetism was to be varied by revolving soft iron pieces in front of the poles. Modern representatives of these machines are to be found in the dynamos of Kingdon, Stanley and others. All the machines up to this time had been of very small dimensions, but in 1849 Nollet began the construction of an alternating machine on a larger scale, but died before it was completed. Machines of Nollet's type were afterward made by Holmes and by the Compagnie d'Alliance of Paris, the latter being called the Alliance machine. The machines were used for light-house purposes. Holmes's earlier machines were continuous current, but later he left out the commutator and still later again introduced it on part of the coils for the purpose of obtaining current to excite his field magnets. This latter plan was introduced after the self-exciting principle had been introduced by Siemens and by Wheatstone. A remarkable machine, historically, was patented in 1848 by Hjorth. In this machine a combination of the permanent and electro-magnet was used—the first to give magnetism enough to produce a current with which to excite the other. A similar idea was developed fifteen years later by Wilde with this difference, that the permanent magnet part was a separate machine. The idea of using part of the current from the armature to excite or partially excite the field magnets was at this time in the minds of a number of workers, and some remarkable machines were patented by the brothers Varley, one of which containing both a shunt and a series winding has been held by some to anticipate the compound winding now in use. In 1867 it seems to have occurred independently to Wheatstone and to Werner Siemens that the permanent magnet part of the Hjorth and Wilde machines might be dispensed with, the residual magnetism being used to start the action. Siemens gave the name dynamo-electric machine to this type, and it has stuck. In order to diminish the fluctuations in the strength of the current during one revolution of the armature, Pacinotti devised his multigrooved armature machine in 1864. This machine did not receive the notice it deserved for a number of years, and in the meantime Gramme produced his smooth-ring armature in 1870. Gramme's machine was soon recognized as being of great merit and its gradual introduction gave rise to increased activity. In 1873 the Hefner Alteneck improvements on the Siemens armature were introduced, and in the remaining 70's quite a number of forms of dynamos were invented, the Lontin type, introduced in 1875, with improvement in subsequent years, being one of the best. The early 80's saw tremendous activity. The patent offices in Europe and America were flooded with inventions of various types of dynamos and motors, of lamps for electric lighting, etc. It is curious how few of these machines have stood the test of time and how well the old types of

Pacinotti, Gramme, Siemens, Alteneck and Lontin in some one of their modifications hold the field. Great progress has been made in the last fifteen years. Machines have assumed enormous proportions, and the number of branches of industry to which they have been applied is now very large. Much has been learned during this time, particularly with regard to alternating currents and their application to the transmission of power, the introduction of multiphase systems being of considerable importance in this connection. In the direction of high potential and great frequency the work of E. Thomson and of Tesla is of great interest.

Of the application of electricity to the production of light and heat little need be said in this connection. The difficulties to be overcome were largely mechanical, and with the progress made we are all familiar. As regards primary batteries there has been, of course, as we all know, considerable progress since the time of Volta. The number of forms brought into use has been enormous, and they have been important in increasing our knowledge of the relative electro-motive force of various combinations and in their bearing on chemical knowledge. It can hardly be said that an ideal primary battery has yet been obtained when we look at the subject from a commercial point of view. Although the subject is not very much to the front at present, however, it is destined to come again, and I have no doubt it will be in a comparatively short time one of our leading industries. The work of Plantê and of Faure and others on secondary batteries has been of great value commercially. They gave rise to several chemical problems, but the main difficulty here also has been of a mechanical kind, and they have not added much to the knowledge of electrical laws.

The transformation of alternating current from high to low potential, and vice versa, by means of what are commonly called transformers, has shown another remarkable development of Faraday's discovery of induced currents. The application of transformers has made it possible to distribute electrical energy over large areas in a moderately economical manner and incidentally has led to considerable increase in the knowledge of the magnetic properties of iron. One of the most important of the applications of electricity is that of electro-chemistry. The chemical action of the electric spark was noticed by Von Groest and Dieman in 1739 in the decomposition of water. Becarri, about the middle of the eighteenth century, obtained metals from oxides through which the spark had passed, and in 1778 Priestley noted the production of an acid gas when the electric spark was passed through air. Similar experiments were made by Cavendish and Von Marum with decomposed ammonia. It is not, however, till after the discovery of the voltaic cell that the subject of electrolysis really begins. I have already referred to the discovery of Nicholson and Carlisle in 1800 and to the subsequent work of Davy and Faraday. The peculiar phenomena of the appearance of separated elements only at the end plates in the electrolytic cell led to considerable speculation and was explained by Grothuss on the supposition that the molecules separated into two parts, one positively and the other negatively electrified, and that these parts formed a chain between the plates along which chemical action traveled by a continual interchange of mates, the end parts going to the plates. This theory was held for many years and is still to be found in some text books. Faraday's work is by the far the most valuable of the early contributions to this subject. He gave the following laws:

"The amount of chemical decomposition in electrolysis is proportional to the current and the time of its action.

"The mass of an ion liberated by a definite quantity of electricity is directly proportional to its chemical equivalent weight.

"The quantity of electricity which is required to decompose a certain amount of an electrolyte is equal to the quantity which would be produced by recombining the separated ions in a battery."

These laws are all of the greatest importance, and the last one clearly points out the reversibility of the electrical process. By forcing a current through an electrolyte it is decomposed and the mutual potential energy of the components consequently increased. By allowing the components to recombine in a battery the mutual potential energy is reduced and a current of electricity is the result. An excellent illustration of this action is exhibited by the secondary battery.

In 1857 Clausius gave a theory of electrolysis and at the same time reviewed the weaknesses of the hypotheses of Grothuss and others. Clausius assumes that the molecules of the liquid are in continual motion, that impacts frequently occur which produce temporary dissociation, leaving atomic groups charged with opposite electricities, and that during these separations any directive agency such as an e. m. f. is able to cause a motion of these atoms in opposite directions. This is probably the first indication of the idea of the purely directive character of the applied electro-motive force, taking advantage of dissociation to produce chemical separation.

The energy side of the problem now began to attract attention and the development of what may be called the thermo-dynamics of electro-chemistry began. Among the most prominent workers in the field have been Joule, Helmholtz, Gibbs, Kelvin, Bosscha and Faure. In 1853 Hittorf made quantitative determinations of the change of concentration near the electrodes when a current is passed through a solution. His work is of historical interest because his work and conclusions formed practically the starting point for what may be called the modern view of electrolysis. Hittorf's experiments extended over several years and served practically to establish the theory of the migration of the ions in the solution. Hittorf communicated the following laws:

"The change in concentration due to current is determined by the motion which the ions have in the unchanged solution.

"The unlike ions must have different velocities to produce such change of concentration.

"The numbers which express ionic velocities mean the relative distance through which the ions move between the salt molecules, or express their relative velocities in reference to the solution, the change in concentration being a function of the relative ionic velocities."

Hittorf's analyses enabled him to give numerical values to these relative velocities. The experiments of Nernst, Loeb and others have extended Hittorf's results and have shown that in dilute solutions the relative velocities of the ions are independent of the difference of potential between the electrodes and are only slightly, if at all, influenced by temperature. Hittorf pointed out that a knowledge of the conductivity of electrolytes should give valuable information in reference to the nature of electrolytic action. A great deal of work has been done in this direction by Horsford, Weidemann, Beez, the Kohlrausches and others. The most notable, perhaps, was the work of F. Kohlrausch, who devised a method of measurement, using alternating currents, by which results of high accuracy were obtained. Kohlrausch's results give the sum of the ionic velocities, and thus combined with the results of Hittorf on change of concentration, which gave the ratios, the absolute velocities can be obtained. It appears from these results that the velocity of the ions in very dilute solutions depends only on its own nature and not upon the nature of the other ions with which it may be associated. For example, the velocity of the chlorine ion is the same when determined from solutions of K Cl, Na Cl or H Cl. The important general law has also been found that the conductivities of neutral salts are additively made up of two values, one dependent on the positive, the other upon the negative ion. If then the velocities of the ions themselves be known the conductivity of a salt may be calculated. The results of Kohlrausch received strong confirmation from some very ingenious experiments by Lodge and Wetham, in which the migration of the ions was made to produce a change of color in the solution and could thus be directly observed.

In 1887 the theory was advanced by Arrhenius and Ostwald that dissociation is directly effected by solution or fusion, and that in very dilute solutions the dissociation is practically complete. Arrhenius holds that the ions carry charges of electricity, positive or negative, dependent upon their nature, but of equal quantity in every ion. The remaining part of the theory is similar to that of Clausius and others. According to this theory the ratio of conductivities for different densities of solution gives a measure of the relative dissociation or ionization. If the act of solution affects the dissociation necessary to admit electrolysis, chemically pure substances ought not to be decomposed by the electric current, and this is found to be the case. It is curious that two substances like hydrochloric acid and water, which separately are insulators, should when mixed conduct readily, and that practically only one of them should be decomposed. This, however, is only one of the many problems still to be solved. Another question is, how do the ions obtain their electric charge? Still another, what is the nature of the force which causes ionization? There are many more.

When we turn to the commercial applications of electro-chemistry we are met with the astonishing evidences of activity. Only twenty years ago there was comparatively little evidence of the importance of this branch of applied electricity. At the electrical exhibition in 1881 electro-chemistry was apparently of comparatively little prominence. A factory which could annually produce a few hundred tons of copper electrolytically was considered a wonder. The production of thousands of tons a month is beginning to be looked upon as commonplace. There is scarcely a metal which cannot be deposited electrolytically with comparative ease, and the prices of some of the rarer metals are going down rapidly. Zinc used to be considered a difficult metal to deposit successfully. It is now produced in some of the Australian mines in almost a pure state from refractory ores at the rate of thousands of tons per annum. Similarly the old method of galvanizing is rapidly disappearing and electro-deposition is taking its place, and this metal is now so deposited on the hulls of ships, on anchors and other smaller articles cheaply and perfectly. A new industry has practically sprung up, and there is every indication that the technical chemist of the near future will have to take an inferior place unless he be also well versed in electricity and electrical appliances. This branch of applied science is revolutionizing many things. It has within a few years produced an enormous improvement in our magazine illustrations and has at the same time reduced the cost of this kind of literature and of atlases and charts enormously. Electro-chemistry is now used on a large scale for the production of bleaching materials, chlorate of potash, alkalies, coloring matters, antiseptics like iodoform, anaesthetics like chloroform, etc.—in fact, it is getting to be difficult even to enumerate the manufactures in which it is used. It has revolutionized the extraction of gold, and plants of enormous capacity are now in use in some of the gold fields, the poorest ores and tailings being made to yield up almost the last trace of the precious metal. The production of ozone by the ton, the purification of sewage, the sterilization of water are all accomplished facts. Some progress has even been made in the introduction of chemicals through animal tissue by electrolysis or cataphoresis, and Röntgen has shown us how to see through the body.

Then, again, we have got the electric furnace, and with it the power to fuse almost the most refractory substances. In this way aluminum is now produced at a few cents a pound, whereas most of us can remember when its price had to be reckoned in hundreds of dollars. In a similar way phosphorus is now produced on a large scale, as is also various carbides, carborundum, acetylene, etc.

It is impossible to look back over the history of electricity and its applications and notice the apparent geometric ratio in which advances are being made and not to speculate on what a giant this science is going to become in another quarter of a century. Undoubtedly no one can study this one branch of science without being persuaded of the great value of scientific work for the advancement of human enterprise.

Lake Maxinkuckee Soundings. By J. T. Scovell.

Lake Maxinkuckee is situated in Marshall County, Indiana. It occupies parts of sections 15, 16, 21, 22, 27, 28 and 34 of township 32, north of range 1, east of the second principal meridian. The lake is a little more than two and a half miles long from north to south, and is a trifle over one and a half miles wide. It has an area of about 1,906 acres. The lake is quite uniform in outline, Long Point, on the west, forming the only acute angle in its gently-curving shore lines. There are three small inlets on the east, and its surplus waters are drained into the Tippecanoe River through a sluggish outlet from the west side of the lake. On the north and east there is considerable boulder clay, but in general the soils and subsoils are sand and gravel. Nearly one-half of the shore line is low, the balance rising abruptly into low hills which in some instances reach an elevation of 50 or 60 feet above the waters of the lake. The low lands along the lake are not extensive; in fact, the drainage area is scarcely larger than the lake itself. The "Inlet," a small stream which enters the southeast angle of the lake, is only about three miles long, and its valley is generally narrow. The little creek that comes in from the northeast drains but a small area. Except along these streams the lake divide is seldom more than a half mile from the lake. While the shores are sometimes low and the water shallow, the bottom along shore is generally hard sand or gravel. The boulder clay, the hills of sand and gravel, the granite boulders and the numerous kettle holes signify that the surface features of the region about Lake Maxinkuckee are due to glacial action. Is the lake a series of great kettle holes or is it part of an old drainage channel? What is the form and substance of its bed? What kinds of vegetation and animal life occur in its waters, and what is its capacity for the support of food and game fishes? A systematic sounding of the lake seemed necessary to an answer of these questions.

In 1896 I drew an outline of the lake from the meander notes of the original survey, on a scale of 8.8 inches per mile or 60 feet to the inch. Early in August, 1897, when I went to the lake to commence sounding, I found Professor C. H. Drybread, with Mr. W. A. Denny and Mr. Delaskie Smith, from the State University, already at work locating lines preliminary to the actual work of making the soundings. They made seventeen lines of soundings across the lake, ten from east to west and seven from north to south. In general the soundings were along land survey lines 80 rods apart. The distance between soundings along these lines was fifteen oar strokes. In sounding they used a block of iron for a sinker and a fine wire for a line. The wire was wound upon a wheel of known circumference, and measurements were calculated from the number of turns made in winding up the line. While sounding Professor Drybread did the rowing, Mr. Smith made the soundings and Mr. Denny kept the record. Professor Drybread made a sketch map and platted in the work from day to day, making profiles of the lines, which frequently suggested mistakes, so that several lines were worked over a second time. In all, the party made nearly five hundred soundings. The party worked carefully, and the sounding was done as accurately as possible under the circumstances. A study of their work reveals some of the difficulties which hinder accuracy in such lines of work. Knowing the length of the line and the number of stations, it was easy to calculate the average distance between stations. This distance varied on the different lines from 190 feet to 300 feet and Professor Drybread's oar strokes varied from 13 to 20 feet in length. This was doubtless mainly due to rough water and wind, perhaps partly to the length of some of the lines. On the line running north across Long Point the distance between stations on the south was 267 feet where the water was quiet, while north of the point in rough water the average distance was 233 feet. The longest strokes were on the north line of section 34, where the water was quiet and the line short. In rough water it was difficult to hold the boat in position while the sounding was made. If the strokes were uniform for the whole length of the line there would be no difficulty, but the irregularity might reach each extreme of variation along any one of the longer lines, involving variations of at least 50 feet from the average. We found places in Lake Maxinkuckee where a distance of 50 feet meant a difference of 25 or 30 feet in depth. Another source of error was in the difficulty of following the lines. The lines were so long that it was not possible to see the flags or signals, and it is not easy to follow a line closely when rowing by a compass, especially when a stop and start must be made every 250 feet. This method of sounding, of course, does not aim at the accuracy attained by the coast survey, with their refined instruments and methods, but it should be accurate at least within 50 feet in distance. To insure this degree of accuracy the work must be done on quiet water and along short lines, so that the man at the oars may do uniform work. All the lines in both directions should be well marked with flags and buoys, so that there may be a check on the distance and alignment every 80 rods. Or the alignment might be directed by a man from the shore, who, standing on a little elevation, could guide a boat over a line from one to two miles long. The check in distance at every quarter-mile line would, I think, insure sufficient accuracy. After sketching in the work of Professor Drybread's party I made about 100 five and ten-feet soundings between those made by Professor Drybread, so that the five and ten-feet contour lines were run in from soundings that were only about 40 rods apart.

At first thought one would suppose that 600 soundings would be sufficient to show well the topography of the lake bed. With this data Professors Eigenmann and Drybread attempted to draw contour lines that would represent the lake bed, but they found many questionable points. Almost every one of the quarter-mile areas not sounded furnished doubtful regions. In exploring these doubtful regions I made about 100 deep-water soundings and recorded about 75 shallow-water soundings, made while running out the outlines of sand bars. In work on the sand bars record was made of stakes located, and not of the hundreds of trial soundings necessary to follow the edges of the bars. The question-points for the north half of the lake are nearly all answered. But the record made by the sounding rod or line is not quite satisfactory. I discovered mistakes enough in the work done to make me wonder if there were not mistakes that I did not discover.

During the summer the lake water is more or less turbid with vegetation and animal life, so that even in shoal water one can gain but little information through the sense of sight. In the autumn or early spring the water is clear and the shallow water can be traced easily by the eye. I shall not feel satisfied with the work until I can confirm all shallow-water work by the sense of sight. Nearly 800 soundings have been made and doubtless 200 more will be necessary to give a satisfactory idea of the irregularities of the bed of Lake Maxinkuckee.

The deepest water found was 85 feet, in the northwest quarter of the southwest quarter of section 22, and the water over the west half of the northwest quarter of section 22 is for the most part over 60 feet in depth, and the east half of the southeast quarter of section 21 seems to be covered with water over 60 feet deep, the deep basin of the lake being the west half of the west half of section 22 and the east half of the southeast quarter of section 21—something over 200 acres. Probably more than one-half the area of the lake is less than 12 feet deep. Much of the bed of the lake is hard sand and gravel, much is fine black mud and some is white mud. The mud is sometimes from four to six feet deep and very thin. Much of the bed is covered with chara, sometimes of stunted growth, but often the growth is luxuriant, stems two and three feet long being common. The bar in the center of the west half of section 22 is covered with from 10 to 12 feet of water and the surface of the bar is covered with a mat of chara from 12 to 18 inches thick, that was so firm as to make the work of sounding difficult. There are several different species of potamageton growing in the lake. They grow in water of different depths, so that my oarsman could tell about the depth from the kind of weed. Large areas are covered with different species of bullrushes; pickerel weed is abundant and so is Vallisneria spiralis and Peltandra undulata. I was able to make a list of 163 plants and trees found in and around the lake.

Photometric Measurements of Different Samples of Oil.

By Charles T. Knipp.

It was a question in my mind for some time whether the difference in the different grades of oil warrants the difference in the price—whether White Seal oil is worth five cents more per gallon than Eosene oil, and if so, what particular quality gives it its value.

The test was a simple one, yet it required care and time in taking the observations to insure accurate results. Five samples of oil were furnished by the local dealers. The oil was taken from large storing tanks and can be considered quite pure. Each sample was tested for its quality and quantity of light, its specific gravity and its "flashing point."

The photometric test was made on a Bunsen photometer bar adjusted to 100 inches between centers. The oil was burned in a student's lamp and balanced against an incandescent lamp burning at 110 volts. The voltage was controlled by a rheostat. A new wick was used for each sample and the lamp was allowed to burn for a few hours before the measurements began. In order to keep the lamp burning at a constant candle power, readings were taken on the bar at intervals of fifteen minutes. The test for each sample extended over from five to seven hours.

The C. P. of the standard at 110 V. was taken as 16.

The specific gravity was determined by a hydrometer and also by weighing on a delicate balance.

In determining the flashing point the open-vessel method was used. The oil was put into a porcelain evaporating dish and slowly heated. It was constantly stirred with a thermometer. A small jet burning at the end of a glass tube was held a half inch above the surface, and the flashing point noted. Each sample was tested in this way four or five times.

The table on the opposite page shows the results of the observation.

The flashing point of safe oil should not be less than about 115° F. or 46° C., having a gravity of from 40° B. to 50° B. The above oils, in my test, all come within the safety limit except the last sample, whose flashing point tested 44:37 C. Of the above the White Seal and the Eosene are held as the best grades, the others are cheaper grades. The White Seal retails for 20 cents, the Eosene for 15 cents and the Headlight for 10 cents. Noting the flashing points of the three samples it would appear that the cheapest oil is the safest. The samples tested are all safe with the exception of the last sample, and as far as quantity and quality of light are concerned there is but little difference.

PHOTOMETRIC MEASUREMENTS OF DIFFERENT SAMPLES OF OIL.

Comparative Table.

Sample of the Oil.	C. P. of Standard V. at 110.	C. P. of Oil.	Oil Consumed per Minute.	Oil Consumed per Hour.	Gms. per I. C. P per Hour.	One gal. at 10 C. P. No. of Hours.	Sp. gr. at 20 C.	Flashing Point.	Flashing Point, When Cooled, from	Allowed to Cool to 20 C. and Again Heated, Flashed at
Eosene	16	10.47	.75	45.42	4.34	68.47	.7847 50° B	49.3°	77.5°—51° 100.5 —53 187 —58.5 151 —63 181 —73	74°
Perfection	16	10.5	.73	43.92	4.18	72.24	.7977 47° B	49.3°	77° —54° 124 —63 155 —75 172 —86	83°
Headlight	16	10.57	.75	45.38	4.29	71.25	.8075 45° B	53.25	75° —54.5° 127 —74 151 —90 180 —101	98°
White Seal ...	16	10.9	.76	45.97	4.22	70.42	.7845 50° B	47.6°	76 —56 129 —67 152 —79 175 —93	87°
Lighthouse ...	16	11.05	.73	44.05	3.98	75.77	.798 47° B	44.37°	77.2°—53.3 124.7 —64.7 150.2 —75 174.6 —84.6	82

Pure Yeast in Bread. By Katherine E. Golden.

Since the introduction by Hansen of pure yeast into bottom fermentation brewing its use has spread to top fermentation brewing, to distilleries, and in fact, to all industries in which fermentation enters as a factor. This almost universal employment is due to the great benefits which accrue from the use of the pure culture. After methods had been devised for the separation of the yeasts it was determined that many which differed from one another very slightly, if at all, morphologically, possessed very distinct properties when considered physiologically. This was shown more particularly in the by-products formed. Many yeasts which give practically the same alcoholic fermentation differ very materially in the characteristics which they impart to beer, so that it was determined that the flavor or "bouquet" of a beer was due primarily to the yeast; that by changing the yeast, keeping all the other conditions constant, a different beer could be produced.

The use of the pure yeast has worked to the great advantage of the brewer, for after a yeast has been selected and careful consideration given to its being kept free from foreign organisms during the brewing, absolute certainty is felt as to the resulting product, definite strength of alcohol is obtained and a constant flavor insured; moreover, the product can be kept indefinitely without deterioration, and can be duplicated when desired. It is evident that where pure yeast is used, elaborate methods for keeping and storing can be dispensed with, for with the absence of foreign organisms there is nothing present in the beer to cause it to deteriorate.

The use of the pure yeast has worked to the advantage of distillers and others as well as brewers, for in distilleries a greater per cent. of alcohol is obtained and in the pressed-yeast factories a higher yield of yeast results.

To determine whether the same advantages which have been obtained in other fermentation industries could not be obtained also in bread fermentation, experiments were made along this line. The experiments are merely outlined in this paper, no details being given.

First, market yeasts were examined microscopically, chemically and in plate cultures. As a rule, the moist cakes, when taken fresh, had a small per cent. of dead-yeast cells, but had present many moulds and bacteria. The dry cakes had few moulds, but had a large number of bacteria. All the dry cakes had alum present, not in sufficient quantity to act on the bread, but the alum evidently had been used as an antiseptic in the mash. Slack sponges were also made of the yeasts, and showed marked variations as regards time and extent of fermentation. This is a test that could be made easily by the housekeeper.

Pure cultures were then made of the yeasts. For this there were used eight moist cakes, six dry cakes, six yeasts from the air (four of these being red yeasts), two from cider, one from flour, four from fruits (grape, guava, persimmon and apple), two separated from corn smut and two from beer, making 31 in all. The pure yeasts were tested (1) for gas production, for which purpose beer wort was used in fermentation tubes; (2) for their action in solutions of sugars—sucrose, dextrose, lactose and maltose; (3) to determine the death limit of temperature for young and old cells; (4) for their fermentative action in slack sponges and stiff doughs, the latter being baked so as to determine the flavor imparted to the bread.

The yeasts were examined microscopically, and it was found that material differences existed among some, while others were so much alike as to be indistinguishable from one another. The wild yeasts and those from the dry cakes were, in general, smaller than those from the moist cakes, and they also developed a film sooner. The yeasts from the moist cakes were large and resembled the beer yeasts. The appearance of the yeasts when grown on solid media will sometimes show variations that aid in the determination.

In gas production there was also much difference, the moist cakes and beer yeasts producing more gas and in a shorter time, as a rule, than the others. Some of the air yeasts produced no gas.

In the sugar solutions there were peculiarities appeared, in that certain yeasts would grow vigorously in one sugar and not in another, the yeasts showing different preferences.

For determining the death limit the yeasts were taken when five days old, 21 days and 30 days, and were tested, beginning at 65° C., for three minutes, then running up until the death point was reached. The death point varied between 80° C. for five minutes and 95° C. for 15 minutes, so that every one of them would be killed in the baking, in even the short time required for biscuit.

In the sponges the characteristics of the yeasts appeared to good advantage, for not only could the fermentative action be easily determined, but also the particular flavor imparted and the keeping properties. The sponges were tested first with sterilized flour, then with unsterilized. Sponges made with sterilized flour were kept for weeks without giving off bad odors. They were then made with unsterilized flour. The odors generated during the fermentation varied from pleasant fruity odors through pungent odors, flat and insipid odors to decidedly disagreeable odors. Some of the sponges would remain in good condition for weeks, whereas in others, growths of moulds would appear in a few days or disagreeable odors were generated. The breads varied also, some being pleasant to the taste, some insipid and a few left a sharp or unpleasant aftertaste. Then the texture differed even with as nearly as possible the same amount of kneading; some were even-grained, while others would show quite an extent of irregularity in the grain. One thing that was quite noticeable in all the breads was the lack of any sourness, and on account of this lack when the breads are tasted, there seems something missing to which one is accustomed.

The experiments on the whole indicated that if the best results are to be obtained in bread-making the yeast will have to be selected with the same care that a yeast is for the fermentation of beer or other liquor. A yeast should possess certain properties to make it valuable in bread-making; it should have a fairly vigorous action, so that the fermentation would take place before any deleterious changes could take place in the dough; it should impart a pleasant flavor and without any disagreeable aftertaste, and should give an even, fine texture to the bread. All these qualities could be obtained by taking the same care in the selection of a yeast for bread that is now taken in the selection of a yeast for beer. Besides, there are great possibilities in the variety of flavors that can be obtained from the use of different yeasts. I presume the reason for the apathy that exists in regard to the selection of yeasts for bread-making purposes is due to the fact that a great deal of the bread is of home manufacture, and if not suitable, it is not so easy for one to change the base of supplies, so that a good deal of competition is eliminated.

A New Laboratory and Its Work. By Robert Hessler.

[Abstract.]

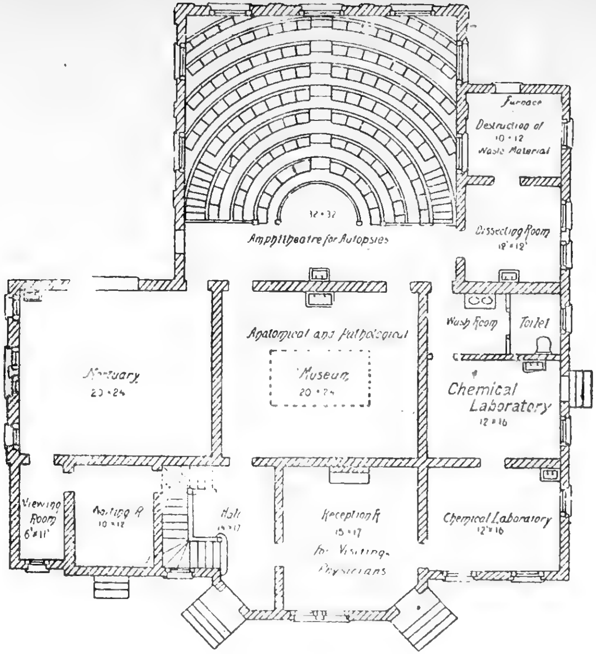
The paper read gave an account of a new laboratory connected with the Central Indiana Hospital for Insane, it being known as the Pathological Department. In the introductory reference was made to the constantly increasing number of insane under the care of the State. A few years ago one hospital was sufficient for the State, now there are four, and all are full. Mere clinical description has been all but exhausted and little additional information is to be gained by such. Insanity is assumed to be due to some change in the brain, it may be ever so minute, and to discover these and to draw deductions for practical application in the prevention and treatment of insanity requires special facilities—and we thus have the laboratory idea.

A description of the different departments of the laboratory was then given: there are separate rooms for chemistry, bacteriology, microscopy, photography and for necropsies; all being properly supplied with apparatus for work.

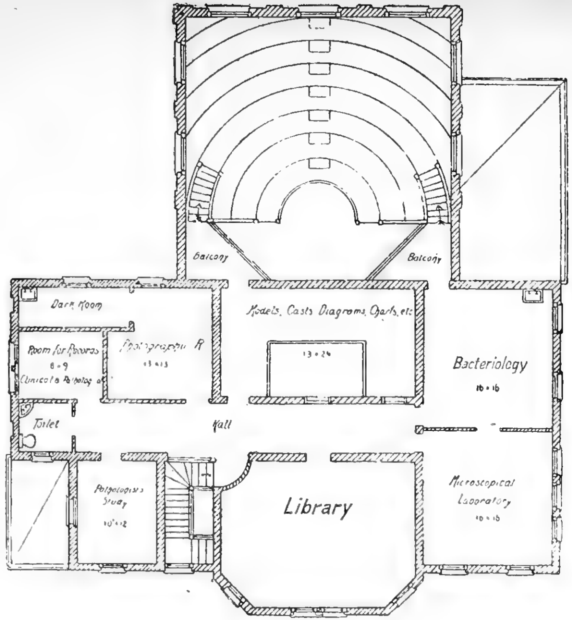
The work will consist, in the beginning, of a course of instruction for the medical staff of the hospital in histology and clinical chemistry, followed by bacteriology and pathology; the examination of blood, pus, urine, new growths, etc., as aids to a thorough understanding of clinical cases; systematic post-mortem examinations; finding and studying the lesions of bodily disease and searching for those of mental disease; original work as opportunity offers.

BUILDING DESIGNED BY GEO. F. EDENHARTER, M. D., SUPT.

PATHOLOGICAL DEPARTMENT.



First Floor



Second Floor

A Case of Microcephaly. By D. W. Dennis.

The subject of this sketch is Edward Basse. He is an inmate of the Institution for Feeble-Minded Children at Fort Wayne, Ind. He was born July 13th, 1883, in Germany. His father died at the age of 49. His mother lives at Garrett, DeKalb County, Ind. He is the sixth child of a family of eight children. Of these six are said to be well formed. One other, Mary, who died at the same institution at the age of fourteen, in 1895, was microcephalic. His parents were second cousins. The following table gives the size of the cranial portion of his head in comparison with nine other microcephals reported by Carl Vogt in 1866:

	Age.	Greatest Length of Skull.	Greatest Width of Skull.	Height from Meatus Auditorius Externus.	Circumference.	Cubic Contents.
Louis Racke (skull at Eichburg)	20	140	122	93	480	622
Gottfried Maehre (skull at Halle)	44	150	112	98	400	555
Conrad Schüttelndreyer (skull at Goettingen)	31	137	117	74	404	370
Edward Basse	14	133.5	110	86	390	?
Michael Sohn	20	131	100	75	370	370
Jena (skull at Goettingen)	26	127	98	75	365	378
Marguerita Machler (skull at Wurtzburg)	33	125	105	70	361	296
Frederick Sohn (skeleton at Berlin)	18	122	100	78	360	460
Jean Moegle (skull at Tübingen)	15	113	96	75	350	395

It will be seen by the table that Basse ranks fourth in the list by three of his measurements and third by one. His measures are all very close to those of Michael Sohn and Conrad Schuttelndreyer, whose skull-contents were 370 c. c. The measurements taken on Sohn and Schuttelndreyer were taken from the skull, however, while the measurements of Basse were taken from the living head covered with thick and not closely cut hair.

Several factors not represented by maximum measurements affect the cubic contents of the skull: the shape of the floor, the amount of surface for which maximum thickness stands, the thickness of the bones, etc. The second of these factors is against the size of Basse's cranial capacity being large, for the maximum is in the region just over the ear, while the frontal and post-parietal and occipital lobes fall rapidly off. I do not think his cranial capacity can be more than 400 c. c. The normal capacity of a child of his age should be 1,350 c. c.; that is, the real capacity is to what it should be as 8 to 27. Thirteen anthropoid apes measured by various observers had an average capacity of 450 c. c. The capacity of Basse's skull, then, is distinctly less than that of many anthropoid apes.

The second anatomical peculiarity to which attention is called is that his head is not in equipoise. The distance from his chin to his throat is as great as my own, namely, 55 mm. The line from his occipital protuberance to his inter-scapular vertebræ is almost a straight line; that is, there is almost no backward projection of his head from his neck. From his meatus auditorius externus to his eyebrows is 80 mm., to the back of his head from same place is but 54 mm.; while in a normal boy measured, the first distance was 88 mm., and the last 94 mm.; that is, in Basse the meatus is 26 mm. nearer the back than the front of his head, when in a normal boy it is 6 mm. nearer the front than the back. The weight of his large face in front is unbalanced by any backward extension of the head. The command which he hears oftenest is "stand up straight, Eddie;" but his anatomy will forever forbid his obeying for long at a time. His forehead recedes in the center 19.7 mm. for a height of 42 mm.; while just over the outer portions it recedes more rapidly still. The greatest transverse diameter of the skull is just over the ear in the postero-frontal and antera-parietal region; forward of this manifest ridge which reaches from ear to ear, the frontal portion of the cranium lessens rapidly. Back of this ridge there is a depression more marked on the right side than the left, which has a depth of about 6 mm., while back of the ridge which forms the posterior border of this depression the skull again narrows very rapidly. The application for his admission to the institution has the clause, "Face of good size, forehead recedes and back of head very small."

His features, including the form of his head, are so monkey-like that it astonishes, if it does not shock, everyone who sees him for the first time. The boys call him "the little monkey face," and when I asked him, at the suggestion of his attendant, "Where is the little monkey face?" he at once pointed to his own face. Once when Santa Claus was distributing presents, a toy monkey was among them; some one asked a little boy who articulates poorly, what it was, and he, after vainly trying to say monkey, pointed to Basse.

There is not in his face a trace of the meaningless vacuity or idiocy which one always notes in the features of the feeble-minded. He has the satisfied, the benevolent, the sleepy, the lazy or sometimes the animated look of the mastiff or the monkey. He is a general pet among the boys, as an animal would be; they can calculate on him; a given treatment to produce a given result; they understand him often better than the attendants do.

He cannot speak a single word; he utters two articular grunts which are slightly modified by lip action; one sounds more nearly like "boo" than anything else; his teacher of speech thinks this means "boy," but the director of his division is equally certain that it means "baby." His tongue, teeth and vocal organs are not at fault at all; the trouble is cerebral.

He hears well and understands simple directions, but he is generally at a loss unless the direction is accompanied by gesticulation. Prof. Von Jagemann's trained mastiff "Bob" had, I think, as large an ear vocabulary and he obeyed with much less hesitation.

Basse's eyesight is good, and he depends largely on it, watches keenly the lips of anyone speaking to him. His transcendant power is imitation; it is the one thing in which he is at home. He will repeat any number of simple things done before him. In an athletic bout (at least in a good-natured one) he meets a stroke with a similar stroke. He will throw kisses if they are first thrown to him. To try him with something new, I adjusted my nose glasses and then handed them to him; he adjusted them to his nose, without the least hesitation, manipulating them exactly as I had done. When I held up one finger he held up one; when I held up two he held up two; this was as far as he could go. He tried several minutes to hold up three, but he could not succeed. While these simple operations were going on, he took all the interest of a specialist in his own hobby. As a retriever will bring back for the hundredth time a stick from the pond with unabated satisfaction, so his pleasure in doing over and over again the same thing never reached a climax; his only condition precedent to perfect happiness seemed to be understanding on his part and continued interest on mine. He has learned to sew buttons on by imitation; but once when the attendant was not there to give him another button he continued sewing without getting a button, although a box full was at hand. So far as I could learn or see, he is incapable of doing work that requires intellectual variation, or that offers alternatives. He can dress himself, but if he happens to button consecutive buttons in alternate holes he cannot (or at least, he could not in one instance) rectify the mistake. His attendant, at my request, asked him to dance; instead of obeying, however, he offered her his hands. She tried every way to persuade him to dance alone; he was evidently not accustomed to solos. He danced with his attendant. In dancing or walking his gait is unique, characterless; he drags his feet or even puts his toes down first.

What, now, is the meaning of Basse's case? Two theories offer themselves. One is that intra-uterine disease of which we can not or at least do not know the cause, produced this malformation or deformity precisely as a child is sometimes born with an undeveloped arm. Hydrocephalus, it is said, is a disease; so also is microcephalus, and beyond this it is both meaningless and causeless except as disease has a meaning and a cause.

A theory for the cause of the disease, so called, of microcephaly, charges it to early ossifying sutures; the following table, taken from Vogt and Montane, shows that this can not always be the case:

	Racke.	Maehre.	F. Sohn.	M. Sohn.	Schütteindreyer.	Jena.	Maehler.	Moegle.	Jean.	Jacques.	Gall, No. 79.	Dumoutier, No. 1.	Dumoutier, No. 2.	Patix.	Gall, No. 190.	Dumoutier, No. 3.
Suture, coronal	....	....	....	....	....	....	....	....	....	....	......	....	......	....	....	....
Suture, sagittal	....	A	A	A	A	....	....	....	....	....	A	....	A	....	....	....
Suture, lambdoidal	....	....	....	....	....	....	....	....	....	....	......	....	......	....	....	....
Suture, squamose	....	....	....	A left	....	A	....	....	....	....	A on left.	....	A on left.	....	....	....
Suture, basilar	A	A	A	A	A	A	A	....	....	....	......	A	A	A	....	....

NOTE.—This table shows the state of the sutures in sixteen cases. A means suture ossified. Five are children under fifteen years of age, and none of the sutures of these are ankylosed; and of the remaining eleven none are ankylosed that would not ordinarily be in normal skulls.

A cure founded upon this theory has been tried, generally, at least, without success. The sutures are opened to give the brain room to grow, but it refuses to grow, and the tendency in re-ossification is to diminish instead of increase the cavity.

Eddie Basse is not sick, as the hydrocephalic patients are. He is healthy, hearty, comfortable, perfectly satisfied with the world as he finds it, and perfectly incapable of conceiving that the order of things might be otherwise. In nothing that has been said is it claimed that there are not microcephalics who are sick, or whose malformation has not been caused by sickness; it is simply maintained that Basse is not. The other theory supposes that microcephaly is atavistic. Atavism does not require that some abnormal organ like supernumerary nipples shall be grown; it equally applies to the suppression of growth in any particular organ, provided that this suppression has left its subject in the normal condition of some adult ancestor.

It is the common property of all students of embryology, that the developing human brain passes through a stage when it has no brain mantel whatever; that is, no cerebrum; and that when the cerebrum begins to grow as diverticula from the fore-brain, its growth is forward, upward and backward until it has covered successively the fore-brain, mid-brain and hind-brain completely. During this backward growth the cerebrum gains also greatly in height and in complexity in many ways, but especially with reference to convolutions. It is equally well known that these successive stages of the growing human brain are represented by the adult stages of the brains of mammals. Now by this theory Basse's brain has been arrested in its development at an anthropoid stage. He cannot speak because his speech centers have not been developed. He cannot reason because his brain stopped in its development before it reached the human stage. This negative statement of the case is not all, however. His power of imitation far transcends that of normal or weak-minded children; that is, he has not stopped in his development merely at somewhat the level of the ape, but he has developed until it is more than human the physiological trait that has given the ape his name, imitation. It is admitted that a rudimentary tail is atavistic; that additional ears on the side of the neck (relicts of the gill-slits that point back to an ancestry that is aquatic) are; but to admit these things and deny a similar significance to Basse's lack of brain and abnormally quickened imitative powers, and his other accompanying animal traits, is like asserting that the chief characteristic of man is lack of tail instead of brain capacity and power of thought.

Everyone has seen cases of atavism which point back to father and grandfather; and it is said that in the most ancient families of Europe, that have in their possession paintings of their ancestors for many generations back, evidence of atavism often appears in children and is a thing to be proud of. But can it point back for thousands or even for millions of generations, if there are so many? Among animals and plants it can, and assent is universal. I have had a lemon brought to school with a perfect sector of the rind a bright green, when all the rest was the usual lemon yellow. The meaning was not far to seek: this part of the rind is reverting back to its ancestor the leaf; the green sector is atavistic. Atavism can also be geological, as Vogt points out; the millionth colt is born with the three toes of the hipparion; but the horse is recent and the hipparion is tertiary.

Atavism explains Basse's case in every particular: his small cranial cavity, his lack of speech, his great imitative powers, his ambling gait, his unbalanced head, his unabated interest in the hundredth repetition of the simplest act, his inability to think.

His sister, Mary Basse, was more animal-like from all reports than he. She had to be waited on as a child, her frame was much more stooped, and she always walked with bent limbs. A detailed study of her skeleton would be of the highest scientific value. But I have not as yet been able to obtain it.

The Relation of Geography to Natural Science and to Education.

By Chas. R. Dryer.

[Abstract.]

Geography is a subject which has points of contact with the whole range of natural science from physics to anthropology. It has intimate relations with a large portion of the work done by the State Department of Geology and Natural Resources, and by the Academy of Science. It is the only natural science which is taught in all the schools of the State. Its presence in the school curriculum furnishes a line of least resistance along which scientific nature study may be introduced into schools of all grades. The personal interest and attention of every member of the Academy was invited to the opportunity here offered for the promotion of scientific education and for the improvement of geographic teaching.

The Susceptibility of Different Starches to Digestive Ferments.

By W. E. Stone.

The question of the nutritive value and digestibility of many kinds of foods narrows down practically to a discussion of the amount of starch which they contain, since in many instances starch is the principal nutritive substance present. A knowledge, therefore, of the percentage of starch which such foods contain is about all we have been accustomed to ask in estimating their comparative value. Examples of such food materials are potatoes and rice, while the various cereal preparations are also characterized by their starch content, although this is not the only nutritive substance which they contain.

It has apparently not occurred to any one, or if so, such conjecture has not found circulation, that possibly there might be an inherent character in different starches by reason of which certain ones might be more or less digestible or nutritious than others. In the case of sugars this thought has lately come prominently to the front, Fischer particularly expressing the belief that certain sugars were more readily assimilated than others. Certain classes of sugars are known not to be digested or assimilated by the human organism. Certain others are not fermentable, and others ferment only slowly and incompletely. A study of the action of animal secretions, such as blood serum and infusions made from various glands, upon the more complex sugars, shows conclusively that different sugars exhibit a greatly varying range of resistance to these agents.

It would seem, therefore, quite reasonable to expect that the starches existing in so many physical modifications and derived from so many different sources might also present some phenomena of this sort. A very serious difficulty, however, in the way of obtaining experimental data to show this is that starch considered as a chemical compound is an exceedingly complex and unstable substance, which under the influence of not extreme conditions is easily changed into other and different substances. Few compounds have been studied more than starch, and yet we know actually very little about it as such. We know much of its derivative and decomposition products, but starch itself is insoluble in its unchanged state, and so defies any direct study of its molecular condition.

It is well known that starch is readily dissolved and at the same time converted into sugar by a number of the so-called enzymes or unorganized ferments. Prominent among these are diastase, one of the enzymes developed in the germination of grains; ptyalin, a characteristic constituent of saliva, and pancreatin, secreted by the pancreas. So far as the digestion of starch is concerned these are probably the principal agencies which change starch from its natural, insoluble form into the soluble and digestible modifications, and a study of their action upon starches ought to throw considerable light upon the comparative degrees of resistance of different starches to digestive action.

Such studies have been made with the coöperation of several students and at different times, leading to results which seem of general interest and application. As material for one study we selected the starches of wheat, maize, rice, the common potato and the sweet potato, as representing not only important food articles, but starches of different botanical character.

These were prepared in the laboratory in preference to using commercial preparations, with the attendant risk of adulteration. Moreover, acids and alkalies are commonly used in the preparation of the starch of commerce, and undoubtedly affect its character. The five kinds of starches were prepared by grating or grinding the raw materials, agitating with cold water, straining through coarse muslin and afterwards allowing the starch to settle from suspension in water after frequent washings. The materials thus obtained were probably quite pure starches, and at least were sufficiently free from impurities or foreign matter to satisfactorily serve the purpose of the experiment.

The plan of the investigation was to subject the different starches under identical conditions to the action of a ferment, and note the time when each kind of starch had been completely dissolved. As an indication of this result the well-known action of starch and iodine was employed. When the starch preparation no longer showed the blue color with iodine it was regarded as completely dissolved or changed.

Exactly stated, it was endeavored to obtain an identical physical condition of all the starches, and then to expose them under constant conditions of temperature and dilution to a uniform solution of the enzyme or digestive ferment.

A weighed quantity of the starches, one gram, or in some cases one-half gram, was heated with 50 or 100 cubic centimeters of distilled water in a boiling water bath during 30 minutes and then cooled to 65° C. An infusion of malt was made by digesting five grams of malt with 200 c. c.

of water at ordinary temperature for two or three hours. Ten cubic centimeters of this malt infusion were then added to each of the starch preparations, which were kept at from 60 to 65° C. The starches were all dissolved in the following order: Sweet potato, 6 to 8 minutes; common potato, 12 to 15 minutes; wheat, 60 to 90 minutes; maize, 90 to 120 minutes.

On diluting the starch in a subsequent series, using the same amount of malt infusion, the time of solution was much reduced, but followed the same relative order. In another series a larger amount of malt was used, and the time of solution was still shorter; for instance, the sweet-potato starch was completely dissolved in $2\frac{3}{4}$ minutes; potato starch, $3\frac{1}{2}$ minutes; wheat, 30 minutes; maize, 38 minutes. These results indicate very conclusively a decided difference in the behavior of these common starches toward diastase.

Similar experiments were then planned with these starches, with the addition of rice starch, and ptyalin, one of the active principles of the saliva.

At first raw starch was employed, but it seems to suffer little or no change even after some hours. Boiled starches, prepared as already described, received each two cubic centimeters of saliva and were kept at a temperature of 40°. After six minutes the potato starch no longer gave any iodine reaction; the sweet potato required 135 minutes; the maize, 145 minutes; rice, 385 minutes; wheat, 400 minutes. By increasing the amount of saliva to six cubic centimeters the following results were obtained: Potato, 3 minutes; sweet potato, 70 minutes; maize, 90 minutes; rice, 165 minutes; wheat, 170 minutes.

On increasing the temperature to 60° potato starch was almost immediately dissolved in two minutes; sweet potato, 25 minutes; maize, 35 minutes; but rice and wheat were not wholly converted in five hours, indicating that a continuation of this temperature for any considerable time destroys the activity of the ferment.

These results were no less striking than those obtained from diastase, although the order of conversion is changed somewhat. Wheat required about 80 times as long for complete solution as potato.

The experiments with pancreatic ferments were carried out in the same way as already described, so far as the staches were concerned. Using commercial preparations of pancreatin at the rate of .2 grams to .2 grams of the starches gave these results: Potato starch was dissolved in 58 minutes; sweet potato, 317 minutes; maize, 337 minutes; rice and wheat not wholly changed after 10 hours. Fresh preparations of pancreatic fluids from the pancreas of both the ox and swine showed that starches of potato, sweet potato and maize were dissolved in the order stated, while rice and wheat were much more resistant and were not finally completely dissolved.

Pancreatin seemed less active than the other ferments, but certain of the starches were much more susceptible to it than others.

To sum up briefly the result of many experiments, which have here been presented only in outline:

(1) The starches of potato, sweet potato, maize, rice and wheat vary greatly in their susceptibility to the action of enzymic ferments.

(2) This variation reaches such a degree that under precisely the same conditions certain of the starches require eighty times as long as others for complete solution or saccharification.

(3) This variation is exhibited toward all of the common enzymic ferments studied, viz., diastase, ptyalin, pancreatin, in the same relative order, with slight exception.

(4) This order, beginning with the starch which is most easily changed, is, for malt extract, sweet potato, potato, wheat and maize; for saliva, potato, sweet potato, maize, rice and wheat; for pancreatic fluids, potato, sweet potato, maize, with wheat and rice unchanged.

(5) Certain of the experiments indicate that the rapidity of the change in particular cases is very clearly proportional to the concentration of the solution of the ferment.

(6) It seems reasonable to assume that the same relative degree of susceptibility exhibited by these starches in the experiments described would still obtain when they are subjected to the action of the same enzymes in the processes of digestion.

(7) The facts here presented have very important bearings upon industrial operations involving the use of starches, upon questions of physiology and nutrition and upon the study of the different starches from the purely scientific standpoint.

In seeking for some explanation of this phenomena only two possible causes suggest themselves—either there is some physical difference in these starches by which the action of the ferments is hindered or held in check, or they are inherently different in their molecular structure, or in other words, are isomeric compounds. The first reason seems to me not a valid one. The starches were in each case thoroughly gelatinized by boiling so as to break up the individual grains and form a transparent gelatinous mass, afterward diluted with water, so as to afford a complete mixture with the solution of the enzymes. The second hypothesis seems reasonable, since we already know that different sugars perfectly soluble are nevertheless quite differently susceptible to the action of ferments and enzymes, and the reason is traced directly to their isomeric condition, i. e., to different molcular constitution. There is certainly nothing improbable in the thought that a similar variation or isomerism exists among starches. Should this explanation, which now seems the only reasonable one to offer, be correct, the theoretical value of the observations presented will quite equal or exceed any practical application they may possess, since the possibility of isomeric starches has not heretofore been entertained.

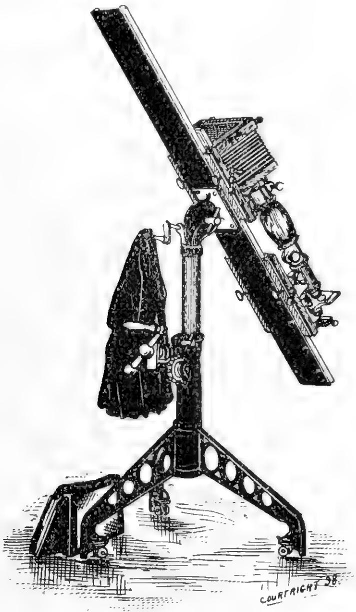
A New Photo-Micrographic Apparatus. By A. W. Bitting.

While it is possible to make excellent photo-micrographs with simple apparatus, a microscope, a camera with a ground glass and a few books cr blocks to make the necessary adjustments, such arrangements are inadequate for laboratory work. To meet the needs of the laboratory many forms of apparatus have been devised, some of which are admirably adapted to the particular work for which they are intended. Most of them have a limited range of adjustment and not well adapted to all kinds of work.

The object of the writer in constructing a new apparatus was to get one more nearly adapted to all laboratory conditions than is now provided.

The requisites of a good photo-micrographic apparatus are rigidity, ease and accuracy of adjustment and adaptibility to all kinds of work. The first condition has been met by using metal in the construction, thus obviating shrinking, swelling and warping, inherent qualities of wood. The second and third requirements have been met in the mechanical construction.

The cut shows the stand in working order in the inclined position. The apparatus consists of an upright cast-iron post supported by three cast legs. The center of this post is bored out to receive the elevating post. Near the top is a sprocket wheel, which is turned by a screw and crank. A binding screw is also placed in the top to clamp the elevating post in position. The upright post, with its legs, stands 28 inches high. The elevating post is 28 inches long, is of two-inch steel tubing, turned to fit the hole in the upright post. A series of holes are drilled into the tubing to receive the sprocket wheel, which raises and lowers it. Upon top of the elevating post is a head-post which receives the bed plate for carrying the camera and microscope. The head-post is turned to exactly fit the inside of the tube and permits the bed plate to be revolved on its horizontal axis. The bed plate is five feet long and five and one-half inches wide. It consists of a piece of three-sixteenths-inch rolled steel, to which is rivited



two dressed half-inch steel tubes. These tubes are placed near each edge and give rigidity as well as serve for guides for the camera and microscope carriages. In the center of the bed plate is a rack for the adjustment of the camera and microscope.

The attachment of the bed plate with the head post is by two dressed circular surfaces and a bolt. Upon the head post is mounted a screw which turns in threads cut upon the edge of the circular plate attached to the bed plate. By loosening the bolt and turning the crank upon the end of the screw the bed plate may be made to rotate upon its vertical axis.

The carriages are twelve inches long, grooved to fit upon the steel rods, and are provided with pinions, cranks and binding screws to make accurate adjustment. The stand is provided with castors so adjusted that it may be thrown on or off its legs with the foot. All the handles are nickel-plated and the whole apparatus enameled black.

With this apparatus it is possible to work in the vertical or horizontal position or at any inclination. The adjustment is easily and quickly made by loosening the binding nut between the friction plates and turning the bed plate to the desired position. The bed plate can be rotated on the horizontal axis to get the advantage of room and direction of light without moving the stand upon its legs. When the bed plate is turned to the horizontal the top of the bed plate is 33 inches from the floor; too low to work with comfort. By raising the elevating post the bed plate may be carried up to the height of five feet. This adjustment makes it possible to always have the work at a comfortable height, either in the sitting or standing position, and regardless of the stature of the operator.

The apparatus has been used for some months in the Veterinary Laboratory of Purdue University. A Zeiss microscope and a long-focus premo camera are mounted upon the carriages (any other microscope and camera can be mounted as easily), and photographs have been taken of parasites, histological sections and bacteria. It has been used in all positions, with fresh and permanent mounts, and the results are entirely satisfactory.

The stand was built by C. W. Meggenhoffen, of Indianapolis.

An Infinite System of Forms, Satisfying the Requirements of Hilbert's Law. By J. A. Miller.

Let Z represent the totality of homogeneous integral forms of four variables (excluding those which vanish identically) which are unchanged by the group of linear substitutions generated by the operators.

$$\begin{array}{llll} S: & Z_1' = Z_2 & \text{and } T: & Z_1' = Z_4 \\ & Z_2' = Z_3 & & Z_2' = -\varepsilon^3 Z_3 \\ & Z_3' = \varepsilon^6 Z_1 & & Z_3' = \varepsilon^6 Z_2 \\ & Z_4' = Z_4 & & Z_4' = -Z_1 \end{array}$$

Where $\varepsilon = e^{\frac{2\pi i}{9}}$

Such a system exists. For inspection shows the elementary symmetric functions of Zi^6 $(i=1--4)$ are unchanged by the group, and hence $\overline{Z}$ consists of an infinite number of forms. The sequel will show, however, that these are not *all* the invariant forms of the group and hence we ask for an expression of the entire system.

1. *To determine analytic expressions for the system* $\overline{Z}$.

Definitions—An i-lettered form is one whose terms each contain i letters. By an invariant we shall mean a form invariant under the group.

An invariant may be expressed as a sum of

one-lettered forms,
two-lettered forms,
three-lettered forms, and
four-lettered forms.

Moreover, since the substitutions are linear, the sum of all i-lettered terms of an invariant is itself an invariant where i is any *one* of 1, 2, 3, or 4.

a. Four-lettered forms.

We shall consider first four-lettered invariants.

Let F be a four-lettered invariant. Where

$$F = Z_1^{\alpha} Z_2^{\beta} Z_3^{\gamma} Z_4^{\delta} + Z_1^{\alpha'} Z_2^{\beta'} Z_3^{\gamma'} Z_4^{\delta'} + Z_1^{\alpha''} Z_2^{\beta''} Z_3^{\gamma''} Z_4^{\delta''} + \ldots\ldots\ldots\ldots$$
$$\alpha+\beta+\gamma+\delta=\alpha'+\beta'+\gamma'+\delta'=\ldots\ldots\ldots\ldots$$

and where any exponent is a positive integer.

Suppose α is the least exponent, then

$F=(Z_1\ Z_2\ Z_3\ Z_4)^{\alpha}$ [a possible four-lettered form + a sum of i-lettered forms.]

Where $i=1---3$,

or $F=(Z_1\ Z_2\ Z_3\ Z_4)^{\alpha}\ [\phi_1+\phi_2]$ (say.)

Since $(Z_1\ Z_2\ Z_3\ Z_4)^{\alpha}$ is an invariant, so also is $\phi_1+\phi_2$, and therefore, by remark above, so also is ϕ_1. Hence ϕ_1 is susceptible of treatment similar to that applied to F, until finally we should have any four-lettered invariant expressed as the sum of invariant forms, of which a type is

$(Z_1\ Z_2\ Z_3\ Z_4)^{n}$ [sum of i-lettered forms] $i=1--3$.

Hence we need seek no expression for an i-lettered form where $i>3$.

b. Three-lettered invariant forms.

Let a term of this invariant be

$$Z_1^{\alpha}\ Z_2^{\beta}\ Z_3^{\gamma}$$

Apply S to this term and the terms resulting until no new terms are obtained, then forming the simplest symmetric function of these terms we reach

$$F_1 = [\, Z_1^{\alpha} Z_2^{\beta} Z_3^{\gamma} + \varepsilon^{3(\alpha+\beta)} Z_2^{\alpha} Z_3^{\beta} Z_1^{\gamma} + \varepsilon^{6(\beta+\gamma)} Z_3^{\alpha} Z_1^{\beta} Z_2^{\gamma} \,] \; [\, 1 + \varepsilon^{3(\alpha+\beta+\gamma)} + \varepsilon^{6(\alpha+\beta+\gamma)} \,]$$

This form is invariant under S, but vanishes identically unless $\alpha+\beta+\gamma \equiv o$ (mod 3). Hence we conclude $\alpha+\beta+\gamma \equiv 0$ (mod. 3)...................... (1)

Apply T to F_1. Immediately there appears, among others, the terms $A\, Z_4^{\alpha} Z_3^{\beta} Z_2^{\gamma}$, and $B\, Z_3^{\alpha} Z_2^{\beta} Z_1^{\gamma}$, A and B being independent of Z; hence terms of this type are in our invariant, and it is necessary to investigate their behavior under the application of S. Treating $Z_1^{\alpha} Z_3^{\beta} Z_2^{\gamma}$ exactly as $Z_1^{\alpha} Z_2^{\beta} Z_3^{\gamma}$ was treated above we reach

$$F_2 = Z_4^{\alpha} [\, Z_3^{\beta} Z_2^{\gamma} + \varepsilon^{6\beta} Z_1^{\beta} Z_3^{\gamma} + Z_2^{\beta} Z_1^{\gamma} \,] [\, 1 + \varepsilon^{3(\beta+\gamma)} + \varepsilon^{6(\beta+\gamma)} \,],$$

which vanishes identically unless $\beta+\gamma \equiv o$. (mod. 3).

Similarly treating $Z_3^{\alpha} Z_2^{\beta} Z_1^{\gamma}$, we obtain a form which vanishes identically unless $\alpha+\beta \equiv o$ (mod 3). Hence we conclude that

$$\left.\begin{array}{l} \alpha+\beta \equiv o \pmod 3 \\ \beta+\gamma \equiv (o) \pmod 3 \end{array}\right\} \quad (2)$$

but $\alpha+\beta+\gamma \equiv o$ (mod 3).

$$\left.\begin{array}{l} \therefore \alpha \equiv o \pmod 3 \\ \quad \beta \equiv o \pmod 3 \\ \quad \gamma \equiv o \pmod 3 \end{array}\right\} \quad (3)$$

It is evident that if t be any three lettered term whose exponents satisfy the conditions (3) that $T^2 : (t) = (-1)^{\alpha+\beta+\gamma}\, t$.

∴ F_1, which is invariant under S, satisfies the relation

$$T^2 : F_1 = (-1)^{\alpha+\beta+\gamma} F_1$$

Hence $\alpha+\beta+\gamma \equiv o$ (mod 2) is a sufficient and necessary condition that F_1 is an absolute invariant under T^2. Similar remarks apply to F_2 and F_3. Hence we conclude

$\alpha+\beta+\gamma \equiv o$ (mod 2)

∴ from 1

$\alpha+\beta+\gamma \equiv o$ (mod 6)...................................... (4)

If, therefore, $Z_1^{\alpha} Z_2^{\beta} Z_3^{\gamma}$ is a term of an invariant form, then

$$\left.\begin{array}{l} \alpha \equiv \beta \equiv \gamma \equiv o \pmod 3 \\ \alpha+\beta+\gamma \equiv o \pmod 6 \end{array}\right\} \quad (5)$$

Applying now S and **T** to $Z_1^{\alpha} Z_2^{\beta} Z_3^{\gamma}$ and to the terms resulting until no new ones are reached, and forming the simplest symmetric functions, we obtain the form:

$$Z_1^{\alpha} Z_2^{\beta} Z_3^{\gamma} + Z_2^{\alpha} Z_3^{\beta} Z_1^{\gamma} + Z_3^{\alpha} Z_2^{\gamma} Z_1^{\beta}$$
$$+(-1)^{\alpha}\left[Z_1^{\alpha} Z_3^{\beta} Z_4^{\gamma} + Z_2^{\alpha} Z_1^{\beta} Z_4^{\gamma} + Z_3^{\alpha} Z_2^{\beta} Z_4^{\gamma}\right]$$
$$+(-1)^{\beta}\left[Z_4^{\alpha} Z_1^{\beta} Z_3^{\gamma} + Z_4^{\alpha} Z_2^{\beta} Z_1^{\gamma} + Z_4^{\alpha} Z_3^{\beta} Z_2^{\gamma}\right]$$
$$+(-1)^{\gamma}\left[Z_3^{\alpha} Z_4^{\beta} Z_1^{\gamma} + Z_2^{\gamma} Z_4^{\beta} Z_1^{\alpha} + Z_2^{\alpha} Z_4^{\beta} Z_3^{\gamma}\right] = \mathrm{P}_{\alpha, \beta, \gamma}, \text{ (say)}, (6).$$

Giving to α, β, γ all possible values under limitations (5), we obtain a triply infinite system of invariant forms.

And this is the complete system, for we can only start with

$$Z_1^{\alpha} Z_2^{\beta} Z_3^{\gamma},\ Z_1^{\alpha} Z_2^{\beta} Z_4^{\gamma},\ Z_1^{\alpha} Z_3^{\beta} Z_4^{\gamma} \text{ or } Z_2^{\alpha} Z_3^{\beta} Z_4^{\gamma}.$$

But all these terms may be found in $\mathrm{P}_{\alpha, \beta, \gamma}$ by a suitable interchange of α, β, γ. Certainly any rational function of the forms $\mathrm{P}_{\alpha, \beta, \gamma}$ is also an invariant. Since $\alpha + \beta + \gamma \equiv o$ (2), at least *one* of the exponents is even.

Corollary 1. $\mathrm{P}_{\alpha, \beta} = Z_1^{\alpha} Z_2^{\beta} + Z_2^{\alpha} Z_3^{\beta} + Z_2^{\alpha} Z_1^{\beta} + Z_3^{\alpha} Z_4^{\beta} + Z_1^{\alpha} Z_4^{\beta} + Z_2^{\alpha} Z_4^{\beta}$

$$(-1)^{\alpha}\left[Z_1^{\alpha} Z_3^{\beta} + Z_2^{\alpha} Z_1^{\beta} + Z_3^{\alpha} Z_2^{\beta} + Z_4^{\alpha} Z_1^{\beta} + Z_4^{\alpha} Z_2^{\beta} + Z_4^{\alpha} Z_3^{\beta}\right] \ldots (6)$$

Cor. 2. $\mathrm{P}_{\alpha, \beta} = -\mathrm{P}_{\beta, \alpha}$; $\mathrm{P}_{\alpha, \alpha} = o$.

Cor. 3. If $\beta = o$ and $\gamma = o$, and $\alpha \equiv o$ (mod 2), we get a one-lettered form,

$\mathrm{P}_{\alpha} = \Sigma Z_i^{\alpha}$ ($i = 1 - - 4$).

$\alpha \equiv o$ (mod 6).

2. To calculate the basis of our system.

*Hilbert has shown that if $\overline{Z}$ is a system of integral homogeneous forms of n variables that F, any form of $\overline{Z}$ can be represented by the expression

$$F = \sum_{i=1}^{m} A_i F_i$$ when m is finite and A_i are homogeneous integral functions of the variables and F_i are forms of $\overline{Z}$.

And in particular if $\overline{Z}$ be defined as a system of forms invariant under a group, that F any form of $\overline{Z}$ may be represented by a rational integral function of a finite number of forms of $\overline{Z}$. This finite number of forms is called the basis of the system.

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*See Mathematische Annallen, Vol. 36.

To find the basis of the forms of $P_{\alpha, \beta, \gamma}$ we need the recursion formulæ, which may be verified by computation.

$$P_{\alpha, \beta, \gamma} = P_{\beta, \gamma, \alpha} = P_{\gamma, \alpha, \beta} \quad \ldots\ldots (7)$$

$$\Sigma Z_i^6 \cdot P_{\alpha, \beta, \gamma} - \Sigma Z_i^6 Z_k^6 P_{\alpha - 6, \beta, \gamma} + \Sigma Z_i^6 Z_k^6 Z_l^6 P_{\alpha - 12, \beta, \gamma}$$
$$- \Pi Z_i^6 P_{\alpha - 18\, \beta, \gamma} = P_{\alpha + 6\, \beta, \gamma} \quad \ldots (8)$$

$$\Sigma Z_i^6 P_{\alpha, \beta, \gamma} - \Sigma Z_i^6 Z_k^6 P_{\alpha, \beta - 6, \gamma} + \Sigma Z_i^6 Z_k^6 Z_l^6 P_{\alpha, \beta, -12, \gamma}$$
$$- \Pi Z_i^6 P_{\alpha, \beta - 18, \gamma} = P_{\alpha, \beta + 6, \gamma} \quad \ldots (9)$$

$$\Sigma Z_i^6 P_{\alpha, \beta, \gamma} - \Sigma Z_i^6 Z_k^6 P_{\alpha, \beta, \gamma - 6} + \Sigma Z_i^6 Z_k^6 Z_l^6 P_{\alpha, \beta, \gamma - 12}$$
$$- \Pi Z_i^6 P_{\alpha, \beta, \gamma - 18} = P_{\alpha, \beta\, \gamma + 6} \quad \ldots (10)$$

$$\Pi Z_i^6 \cdot \Sigma Z_i^6 Z_k^6 P_{\alpha, \beta, \gamma} - \Pi X_i^{12} \Sigma X_i^6 P_{\alpha - 6, \beta - 6, \gamma - 6} - \Pi Z_i^{18}$$
$$P_{\alpha - 12, \beta - 12, \gamma - 12} + \Sigma Z_i^6 Z_k^6 Z_l^6 P_{\alpha + 6, \beta + 6, \gamma + 6} -$$
$$P_{\alpha + 12, \beta + 12, \gamma + 12}.$$

Making $\gamma = o$ in 8, 9, 10, we get recursion formulæ for $P_{\alpha, \beta}$.

By a repeated and successive application of the formulæ 8, 9, 10 to any $P_{\alpha, \beta, \gamma}$, it is expressed as a rational integral function of forms $P_{\alpha', \beta', \gamma'}$ whose greatest index is 18, and therefore finite in number, and which is therefore the basis of the system.

I will add, however, that by a somewhat tedious reduction it can be shown that the system can be expressed as rational functions of

$$\Sigma Z_i^6, \Sigma Z_i^6 Z_k^6, \Sigma Z_i^6 Z_k^6 Z_l^6, Z_1 Z_2 Z_3 Z_4, P_{9,3}, P_{15,3}, P_{6,3,3}, P_{6,9,3}.$$

Rate of Decrease of the Intensity of Sounds With Time of Propogation. By A. Wilmer Duff.

[Abstract.]

PART I.—THEORETICAL.

The intensity of sounds spreading in spherical waves from a source would, if no part of the energy of vibration were lost in the passage, vary inversely as the square of the distance. But it is certain that a considerable proportion of the sound energy must in every second be converted into heat, though no attempt seems to have been made to determine experimentally what proportion this is of the whole. The transformation of energy of vibration into heat energy takes place in three ways. In the first place, the viscosity or internal friction of the air must cause a diminution of the vibrational energy and the production of heat. Again, in each condensed part of a sound wave heat is produced by the condensation; this causes a rise of temperature and an immediate tendency for radiation of heat and conduction of heat to take place. Similarly a fall of temperature takes place in the rarefied part of the wave with a similar tendency to radiation and conduction. Now, the greater the extent of this radiation and conduction, the less will be the amount of vibrational energy handed on and consequently the less the intensity of the sound. In addition to spherical spreading, viscosity, conduction and radiation, two other sources of diminution of intensity might be mentioned, namely, atmospheric refraction and lack of atmospheric homogeneity; but these two latter influences are only occasional or local, while the former are invariable and universal.

Several eminent physicists have given theoretical discussions of the effects of viscosity, radiation or conduction separately or of two of them simultaneously. Thus Stokes, in 1845, studied the effect of viscosity and deduced numerical results, and in 1851 he found a formula for the effect of radiation, but calculation from this result is still impossible because of our total ignorance of the rate of radiation of a gas. Rayleigh has applied Stokes' method to estimate the effect of conduction. These investigations referred to plain waves only. Kirchoff, in 1868, discussed the effect of conduction and viscosity together on plane waves, and indicated the result for spherical waves also. Brunhes has recently examined the effect of conduction on plane waves, obtaining a result in accord with those of Kirchoff and Rayleigh.

In order to deduce any intelligible results from the observations, I have made it necessary to either assume or establish a law of diminution of intensity in spherical waves, taking account of viscosity, radiation, conduction and spherical spreading simultaneously. As considerable doubt might attach to a general formula framed by the superposing the formulæ already obtained for the separate effects enumerated, it seemed advisable to undertake a new theoretical investigation for spherical waves affected by viscosity, radiation and conduction. (This discussion is here omitted, but will be printed in full elsewhere.) The conclusion which we arrive at is that the intensity varies as

$$\frac{e^{-2mr}}{r^2}$$

provided the proportional rate of fall of temperature of the gas by radiation be small compared with the number expressing the pitch of the sound. In the experimental work described in the second part of this paper sounds of very high pitch were employed, so that the above condition was satisfied. By this means a value for the constant radiation is finally deducted, and it is found to be small in comparison with the pitch-number of any ordinary sound, and so the solution obtained above may be considered as holding true, at least very approximately, for any sound of moderate pitch.

PART II.—EXPERIMENTAL.

Any attempt to compare sound intensities is attended by great difficulties. The term intensity can itself be understood in two ways—firstly in the subjective or physiological sense of loudness, and secondly, in the objective or dynamical sense of rate of flow of energy. The only case in which there seems to be a constant proportion between these two is when we compare sounds of the same pitch and quality. In deducing results from the experiments, I have made the following assumption: When two faint and diminishing sounds are indistinguishable by the ear as regards pitch and quality, the minimum of energy flow required for audibility is the same. While this assumption cannot be fully justified, it seems at least inherently highly probable, and can at most differ but slightly from the truth. The errors consequent on this assumption probably lie well within the experimental errors in the following method:

A large number of very small whistles were made of as nearly as possible the same shape and dimensions. From these the eight that seemed most similar were chosen and mounted on a wind-chest in such a way that any number could be blown under a definite pressure measured by a water monometer. The distances at which each pair and the whole eight just became inaudible were then determined. It was found that near the limits of audibility the sounds were indistinguishable in quality. Let R be the distance at which all eight whistles blown simultaneously became inaudible and r the mean distance at which two became inaudible. Then at a distance r the mean rate of energy-flow from two whistles equals the minimum for audibility, and hence that of eight whistles equals four times the minimum for audibility, while at distance R, the rate of energy-flow of eight whistles equals the minimum for audibility. If now, in accordance with the above assumption, the minimum be the same in both cases,

$$\frac{e^{-2mR}}{R^2} : \frac{e^{-2mr}}{r^2} :: 1 : 4$$

$$\text{and } \therefore m = \frac{\log_e \left(2 \frac{r}{R}\right)}{R - r}$$

The observations were made at a very quiet place on the River St. John, in New Brunswick, Canada, the whistles being sounded on one side by an assistant and the sounds listened to on the opposite side. Only times when there was no appreciable wind were chosen for observation. When a wind sprang up in the course of a set of observations the work was discontinued and the observations discarded. In order to eliminate the effect of reflection from the banks, several different stations for sounding and directions for observing were tried in different sets of observations. The orifices of the whistles were always kept turned directly toward the observer. To avoid errors due to the tiring of the ear, in some cases the observations on the pairs of whistles were made first, and in other cases those on the eight whistles. Various devices were tried to eliminate the effect of bias in determining the distance of inaudibility. As regards the difficulty of determining the point at which the sounds became inaudible, this was found much less than was expected. Nevertheless, there was always a space in which it was doubtful whether the sound was heard or imagined. The middle point of such a space was taken as the most probable position of extinction.

As regards the success attained in attempting to make the different pairs of whistles of equal intensity, the following figures may be quoted. (These were the only cases in which the position for each pair of whistles was finally calculated. In general the position for each pair was marked by a stake and the mean finally taken for measurement.) In the first the mean distance was 1,693 feet and the distance of the separate observationstions for the mean —28, —18, +5, +41, a total range of 69 feet. In the other the mean distance was 2,078 feet, and the distances from the mean were —39, —15, +9, +45, a total range of 84 feet. Here something must be allowed for unavoidable bias, but yet the result seems fairly satisfactory.

The whistles were made of the stopped-organ-pipe form. In the absence of facilities for the purpose their exact pitch was not determined until after the experiments had been made. The pitch was then determined by using a high pressure sensitive flame to find the nodes of the stationary waves produced by reflection from a wall. The semi-wave lengths are as follows, in inches: .98, .97, .95, .95. .97, .95, .95. .96. The mean of these is .960, corresponding to a vibration frequency of 6,820. The following table gives the series of readings made and the values of m deduced, all lengths being in feet:

SERIES.	r.	R.	Temp.	m.
1......................	1260	1660	80° F	.0010
2......................	1333	1699	74	.0012
3......................	2078	2473	60	.0013
4......................	1502	1834	70	.0015
5......................	1959	2335	68	.0013

To enable us to appreciate the meaning of these figures, it may be noted that, since the eight whistles gave a sound of four times as great an intrinsic intensity as the mean pair of whistles, this sound should, if no cause except spherical spreading affected the intensity, be audible just twice as far, while, as a matter of fact, owing to the other causes enumerated, it was usually audible only about one and one-quarter times as far. The value of m may be expressed by saying that, excluding the effect of spherical spreading, the intensity of the sound died off about one-fourth of 1 per cent. for each foot of advance.

For such rough determinations of a quantity very difficult to determine at all, the agreement between the values of m, as shown by the last column, seems very satisfactory.

If now we return to the theoretical investigation it can be shown that the value of m consists of the sum of three parts, due, respectively, to viscosity, conduction and radiation. Since the constants of viscosity and conduction are known, while the full value of m has been found by expeiment, it can be calculated that the effect of viscosity is to produce a diminution of intensity amounting to one-fortieth of 1 per cent. per foot of advance; of conduction, one-seventieth of 1 per cent., while the remainder, amounting to one-fifth of 1 per cent., is due to radiation.

It may be questioned whether all of the part of the effect thus attributed to radiation is really due to that cause and whether part of it may not be due to refraction and heterogeneity of atmosphere, as stated earlier. That it is not due to refraction is pretty certain, for refraction tends to produce actual sound shadows of the surface of the earth or water at certain distances, and so would be very marked when acting. It also varies greatly with the gradient of temperature, being nonexistant when the temperature does not change as we ascend for some distance. Now, both the distances of observation and the state of the atmosphere would vary greatly, and hence if the circumstances were such that refraction had any considerable effect the values obtained for m would vary widely among themselves. Moreover, calculation will show that for the elevation of sounding station and observing station employed, the distances at which refraction would appreciably affect the value of m would be much greater than those employed in the observations.

As regards invisible striae of water vapor, these must have had a very small effect, if any at all, for the effect should vary very greatly with the state of the atmosphere, and this varied very widely, some observations being made at noonday of very hot days, others between 7:30 and 8:30 in the evening, and on one occasion, while the sky was overcast and the atmosphere heavily charged with water vapor just before a storm. Probably, therefore, nearly all the effect mentioned is due to radiation.

Now, the theoretical investigation shows that the effects of viscosity and conduction decrease very rapidly with decreasing pitch, being proportional to the squares of the vibration frequency, while the effect of radiation is independent of pitch. We conclude, therefore, that for sounds of ordinary pitch the effect of viscosity and conduction on intensity is practically negligible, while the effect of radiation amounts to about one-fifth of 1 per cent. per foot of advance.

The Constant of Radiation of Air. By A. Wilmer Duff.

[Abstract.]

Assuming that for small differences of temperature, radiation takes place according to the law stated by Newton, namely, in proportion to the excess of temperature of the radiating body above its surroundings, we may define the constant of radiation of air as the rate of cooling (by radiation) of a body of air which has been raised one degree above the sounding mass. From the results of the preceding paper it can be calculated that this is about 8.3 degrees per sec. This is equivalent to saying that in the first hundredth of a second the heated mass would

cool one-twelfth of a degree, or if a mass of air be heated to any excess above the surrounding mass it will fall to one-half of that excess in about one-twelfth of a second.

For reasons stated in the preceding paper it is evident that this value must err rather in being too large than in being too small.

Preliminary Results by a New Method for the Study of Impact.*

By A. W. Duff and J. B. Meyer.

The purpose of this paper is to briefly describe an apparatus for the study of impact of masses of wood on one another, and to state a few results obtained by means of it. It was intended to include in the investigation not only the change in the relative velocity of the impinging bodies produced by impact, but also the length of time the bodies are in contact, the closeness of approach produced by their mutual compression, and the internal vibrations to which impact gives rise. The apparatus was constructed by Mr. Meyer, and the present results obtained by him early in this year, but only a small part of the contemplated work was completed when it had to be discontinued. Calling, as usual, the ratio of the velocity of separation after impact to the velocity of approach before impact the coefficient of restitution, it may be stated that the results to be given here are only a few isolated determinations of the coefficient of restitution and of the time of contact.

In principle the apparatus consists of a block dropped vertically on a much larger mass of the same material, the circumstances of the impact being recorded in a curve traced by a pencil attached to the block on a vertical revolving drum covered with a sheet of paper. To describe the apparatus more fully, it consists of two vertical beams mortised in a massive cross-shaped base, the beams adjustable so that the space between can be regulated. The height of the beams is 8 feet. Between these beams as guides the block can descend with comparatively little friction. On the base, the larger of the two impinging masses, or the plate as we shall call it, is rigidly clamped. Immediately in front of the beams is fixed on cone bearings a vertical rotating cylinder around which a sheet of paper is wrapped. The cylinder is 2 feet in diameter and 2½ feet in height. Fastened to the top of the descending block is a small removable board, to which is attached a brass tube carrying a pencil. The tube is secured in position by a catch attached

* This paper is an abstract of a thesis presented by Mr. J. B. Meyer for the degree of B. Sc., and placed in the library of Purdue University.

to a lever arm. By a crossbar placed at any desired height, this lever is tripped up as the block descends, the pencil is released and shot forward by the tension of rubber bands so as to press against the paper-covered cylinder. Were the cylinder at rest, the pencil would merely describe a vertical line, turning back on the same line at the moment of impact. When the cylinder is in rotation the pencil describes a curve which is abruptly reversed at the moment of impact. As the block usually bounces several times before coming to rest, this curve consists of successive loops meeting at sharp angles which correspond to the successive impacts. This will be fully understood by a glance at the record sheet shown on the wall. If now we draw tangents to these curves at a point of impact, and denote by Vi the velocity of the block immediately before impact, by Vr its velocity immediately after impact and by Vc the velocity of the surface of the cylinder at the moment of impact, then—

$$\frac{\frac{Vr}{Vc}}{\frac{Vi}{Vc}} = \frac{\tan a'}{\tan a} = \frac{\frac{y'}{x'}}{\frac{y}{x}},$$

or, if x' be taken equal to x, we have $e = \frac{Vr}{Vi} = \frac{y'}{y}$, the coefficient being considered negative, since Vr is a negative quantity. Thus the actual velocity need not be known so far as the determination of e is concerned, and the process is reduced to the drawing of two tangent lines and the measuring of the ordinates corresponding to equal abcissae measured from the point of impact.

To enable us to find the time of contact during impact, or, briefly, the duration of impact, it is necessary to know the speed of the cylinder. Now once in each rotation of the cylinder it thrusts up a vertical wire attached to the short arm of a lever, causing the longer arm to descend and complete an electric circuit and give a record on the drum of an electro-chronograph. The speed of the drum is determined by a parallel record of the time of vibration of a second's pendulum which completes another electric circuit whenever it passes through the vertical. The electro-chronograph thus used is one made by the Geneva Society, of Switzerland; its drum can be made to rotate once in a second under the control of a Foucault regulator. From the curve exhibited it is plain that the impinging bodies compress each other during the first period of contact, and upon separation they more or less regain their original forms; so that at each rebound a portion of the line traced by the pencil when at rest is intercepted between the curves traced by the pencil. Dividing the length of the portion so intercepted by the product of the circumference of the cylinder and the number of revolutions per second we have the duration of contact. It is not necessary always to determine the speed of the cylinder by means of the chronograph, for, having once found a good average value for the velocity of impact for a certain height of drop, the velocity of the cylinder at any other impact from the same height of drop can be found from the inclination of the impact curve.

$$\text{Thus } \frac{Vi}{Vc} = \tan a$$
$$\text{and } Vc = \frac{Vi}{\tan a}$$

It may also be noted that the amount of mutual compression at impact is at least approximately given by the extent to which the curve sinks below the zero line.

By making the moment of inertia of the cylinder large, its speed during the time of contact may be considered as constant. It should be noted that the results do not depend upon the friction between the block and the guides, for we are concerned only with the actual velocities just before and just after impact, no matter how they are attained.

PRELIMINARY TESTS WITH THE APPARATUS.

The method here employed for the determination of the coefficient of restitution, consists in principle, in the dropping of a mass on a plate so large that the motion communicated to it may be neglected, so that the relative motion is merely that of the block. As a matter of fact in the arrangement adopted, the stationary plate is only about ten times as large as the block, but it is so solidly clamped to the base of the massive structure that it is assumed to be practically immovable. It might however be suspected that the result would depend upon the stationary block, *i. e.*, its mass, or its vertical thickness, for evidently if it were too thin it would in reality be on the elasticity of the base beneath it that the force of rebound would depend.

To test this point, a short beam of well-seasoned cherry was taken whose cross-section was a rectangle, one side of which was three times as long as the other, so that the beam was three times as thick in one direction as that in the other. The actual dimensions of the beam were $2' - 1\frac{1}{2}'' - 4\frac{3}{4}''$.

If these thicknesses for the stationary mass be too small, it should be shown by the coefficient of restitution being different for impacts in the direction of the greater thickness and in the direction of the smaller thickness. The impinging block used was also cherry, the grain being vertical and the impinging surface turned into a hemisphere of 7 centimeters radius. The value of e found with the greater thickness of the beam vertical was .35 and with the smaller thickness vertical was *.36*. Another beam of the same material was then taken whose cross-section was a square, the side being equal to the greater side of the rectangle in the preceding. The mean value obtained by large number of impacts was *.355*. It will be understood that the mass in this case was three times as great as that in the preceding cases, and that all three values agreed very closely. Hence it is assumed that the thickness in these cases was sufficient and that practically the base acted like a very great mass.

In the preceding, the drops were from the same height. The next point tested was whether or not the height was so great that the limit of elasticity of the wood was passed. A series of determinations was made with all other circumstances similar, but with different heights of drop each time, varying from 1 to 6 feet, and the values of e while varying from *.34* to *.38* showed no regular dependence on the height of drop. It may be stated that such differences as here obtained occurred frequently, although usually smaller in amount. They are mostly attributable to the lack of homogenity in parts which seem superficially quite similar in structure. The mean value of e in this series was *.363*.

It may be stated that the same impinging block was used over and over again. Had there been any effect produced by the crushing of the impinging surface of the block, it seems evident that it would have shown itself in a change of the value of e. As no such appeared, it seems evident that no such effect existed. To settle the question, however, a series of determinations was made with a newly turned impinging surface each time. The radius of curvature was much larger in this case. The result was that the values for e obtained in these tests were practically constant and unchanged by the successive impacts of the impinging surface, but were notably large with this larger radius of impinging surface, the mean value being *.42*, while with the smaller radius of curvature it was *.36*. The effect of curvature will be spoken of later.

In all the preceding tests the impacts were on new and undinted surfaces of the base plate. This was necessary because an effect due to the dinting of the plate had been observed though not accurately examined. We now more carefully tested this point and found that under successive impacts on the same spot of the base plate the value of e rose steadily from the earlier value of *.36* to *.49*, showing a permanent effect due to a crushing of the material of the base plate. The radius of curvature as formerly was 7 cm.

Again, to find the effect of curvature of the impinging block, a series of tests were made, first with a curvature of 3 cm., then of 7 cm., and then of 10 cm., and it was found that the eorresponding values of e were—for 3 cm., *.32;* for 7 cm., *.37;* for 10 cm., *.42*, thus showing that the value of e increased with increasing values of the radius of curvature.

The last point tested was the effect of the *mass* of the impinging block, those so far used weighing about one kilogramme, or two and a fifth pounds. The mass was now doubled and the radius of curvature being 7 cm., as in the earlier tests, a value of *.36* was obtained. It was now found that with the height of drop *120 cm.*, or *4 ft.*, the value of *e* remained the same as before, namely, *.36*, but that for a drop of *6 ft.*, the value decreased to *.33*, and with a much heavier mass the value sank to *.25*. Attention might be here called to the fact that there might seem to be some contradiction between the statements that while greater height and therefore greater force of impact with the light block on fresh parts of the base plate did not affect the value of *e*, an increase of the impinging mass showed a decrease in the value of *e* with increasing force of impact, while successive impacts on the same spot showed an increasing value of *e*. The explanation would seem to be that whereas beyond a certain limit, increasing force of impact produced an initial crushing of the surface from which there is only imperfect recovery, when successive impacts take place on the same spot, at each impact there is a greater area of resisting surface encountered, and also less unrestored crushing, and hence a greater velocity of rebound with a consequent increase of *e*. The point seems to merit a more careful investigation than it received in these purely preliminary experiments.

These tests point out the limits as regard mass of impinging block and height of fall within which it is safe to work in comparing the coefficients of restitution of different materials. It also shows that for a comparison of different materials it is necessary to adopt the same curvature of impinging surface and to use a fresh part of the base plate for each impact. Hence in the following comparison the masses of the impinging blocks are uniformly one kilogramme, radius of curvature of the impinging surface *10 cm.* and the height of fall 120 cm.

TABLE OF COMPARISON.

Material.	*Value of e.*	*Duration of Contact.*
White pine	.38	.0017 seconds.
White poplar	.42	.0016 "
Cherry	.42	.0016 "
Hard maple	.45	.0012 "

In the above it will be understood that in all cases the grain of the impinging block was vertical and that of the base plate horizontal. The first remark that may be made about these results is the surprising closeness of the values of *e* for the different materials, varying between *.38* and *.45*, while the duration of contact varied between *.0012 sec.* and *.0017 sec.* It may also be noted that the values of *e* varied in the inverse order to the duration of contact.

A few determinations were also made with the grain of both block and plate horizontal, the other circumstances, curvature and height, being the same as in the above table.

These results are given as they be of interest but very little reliance can be placed upon them as they were somewhat hastily made and time did not permit of repetition.

Material.	*Value of e.*	*Duration of Contact.*
White poplar	.42	.0024 seconds.
Cherry	.49	.0014 "
Hard maple	.56	.0012 "

These seem to show in a more pronounced manner the connection between duration of contact and the coefficient of restitution, but for reasons above stated we hesitate to regard the law as established.

It may be added, by way of a postscript of less serious content, that the length of time of contact of a base ball with a bat and the corresponding value of the coefficient of restitution, were determined by this method. These values are for the duration of contact $\frac{1}{160}$ seconds, and for the coefficient of restitution [illegible].

Variations in the Spectrum of the Open and Closed Electric Arc.

By Arthur L. Foley.

[Abstract.]

The image of a normal electric arc appears to consist of three regions—a central violet portion, an outer yellow sheath or flame and an intermediate sheath of blue. By means of a Rowland grating and a Brashear mounting, and a concave mirror to focus the image of the arc upon the slit, a photographic study was made of the spectra of these regions under four conditions: (1) A vertical arc and a vertical slit, (2) a vertical arc blown out by a horseshoe magnet, (3) a horizontal arc and a vertical slit, (4) a horizontal arc and a horizontal slit.

The accompanying table gives the results of a study of the three regions of the arc with the slit vertical and through the center of each region. Two exposures were made in each position, three seconds and thirty seconds in the violet and blue regions, ten seconds and thirty seconds in the outer or yellow sheath. An exposure of three seconds in the latter brought out only ten lines.

ELEMENTS.	REGION 1. CENTRAL VIOLET.		REGION 2. BLUE.		REGION 3. OUTER YELLOW.	
	Plate 1. Exposure 3 Seconds.	Plate 2. Exposure 30 Seconds.	Plate 3. 3 Seconds.	Plate 4. 30 Seconds.	Plate 5. 10 Seconds.	Plate 6. 30 Seconds.
C	313	450	60	274	1	8
Fe	84	107	29	91	47	74
Ca	14	17	3	15	8	15
Ti	0	20	0	1	0	1
K	3	4	2	3	2	3
Al	2	3	2	2	2	2
Mn	2	2	0	2	1	1
Cu	0	2	0	0	0	0
Ba	1	2	0	1	1	1
Na	1	1	0	1	0	1
Si	1	1	1	1	0	1
Not identified	4	50	0	1	0	0
Faint or blurred	29	37	38	29	6	13
To. No. lines identified	421	709	97	391	62	107
To. No. lines visible	454	796	135	421	68	120

Whole number of lines visible, 1994.
Whole number of lines measured, 1842.
Whole number of lines identified, 1787.

The table shows that the lines rapidly decrease in number as the slit is moved from the center of the arc to the outer edge. This is due chiefly to the fading out of the carbon bands, only a few of the stronger carbon heads being visible in the outer sheath. But the fading out is not confined to the carbon, as the lines of all the other elements of the table show the same tendency, though to a much smaller degree.

The lines of the table (which extends from $\lambda = 3092$ to $\lambda = 5015$) were not only measured and identified, but their intensity was estimated at three points—at the upper end near the positive carbon, at the center and at the lower end near the negative carbon. The Ca and Fe lines were relatively much stronger in the outer regions than the lines of any other element. All the lines of any one element did not fade out at the same rate. Neglecting for the present the thickening of the lines at the poles and considering each region as a whole, it may be concluded that the differences observed in the spectra are due chiefly, if not entirely, to temperature differences, and that there are no lines having maxima in the outer regions. A study of the photographs taken under the three other conditions before mentioned confirms the conclusion.

The spectrum of the inclosed electric arc (a Helios Electric Co. lamp) did not differ from that of the open arc when the arc was first started. But after a minute or two the arc shortened and the metallic lines began to disappear. After ten minutes 100 volts would maintain an arc scarcely one cm. long. The metallic lines had disappeared almost completely. The carbon and cyanogen bands were even stronger than in the first photograph. Air was then passed through the hollow carbon into the arc and globe. The arc lengthened and the metallic lines reappeared. When the current of air was shut off and a stream of CO_2 turned on the metallic lines were weakened, but they did not disappear as long as the CO_2 was flowing.

It appears that a comparatively rapid disintegration of the carbon poles is necessary to furnish enough material in the arc to bring out clearly the metallic lines, which are due to very small quantities of the metals contained in the carbons as impurities. The rapidity of the disintegration depends upon the amount of O present in the globe. After the O had become exhausted by allowing the arc to burn a few minutes the wasting away of the poles was very slow, indeed. When CO_2 was introduced the wasting of the poles increased, and, as noted before, the metallic lines appeared. Air still further increased the disintegration of the poles and the brilliancy of the metallic spectra. When pure O was passed into the globe and arc the poles were rapidly consumed. The metallic spectrum was very bright, likewise the carbon any cyanogen bands. When the lower hollow carbon was replaced by a carbon with a sulphur core (made by pouring hot sulphur into a hollow carbon) S vapor filled the globe and displaced the air very soon after the arc was started. The metallic lines did not appear, but the carbon and cyanogen bands were strong.

The Spectrum of Cyanogen. By Arthur L. Foley.

[Abstract.]

This investigation was made with the grating and accessories described in a previous paper and with a Helios enclosed arc lamp. The lamp was modified to allow the lower carbon to project below and outside the globe. A solid upper carbon was used. The lower carbon, which was hollow, had several small holes bored through its walls near the upper end, so that a gas blown in at the lower end would be introduced into both the arc and the globe. The lamp was not air-tight, but the circulation was very slow when the lower end of the hollow carbon was closed. When a gas was blown into the globe the admission of air was prevented by the escaping gas.

By the term carbon bands will be meant those heading near $\lambda = 4737$ and $\lambda = 4382$. The bands heading near $\lambda = 3883$, $\lambda = 4216$ and $\lambda = 3590$ will be called the cyanogen bands, though the researches of Augström and Thalèn, Lockyer, Liveing and Dewar, Kayser and Runge, Crew and others are very conflicting on this question.

When the spectrum was photographed immediately after starting the arc it was identical with the spectrum of the open arc. After ten minutes the metallic lines had disappeared almost completely. The cyanogen and carbon bands remained strong even when O, CO_2 and S vapor were forced into the arc and globe.

It was thought that the cyanogen bands might have been due to the nitrogen of the air contained in the porous carbon poles. To remove the air the carbons were placed in a small air-tight iron cylinder, which was connected by tubes with an air pump, and a cylinder or CO_2. The cylinder containing the carbons was placed in a furnace and kept red hot for two hours; the air pump was worked continuously. The carbons were then allowed to cool in an atmosphere of CO_2, in which they remained for several days. The operation was then repeated and the carbons cooled as before.

When the treated carbons were placed in the lamp and a continuous stream of CO_2 was passed into the arc and globe, the cyanogen bands appeared to be a trifle weaker and the carbon bands a little stronger than with the untreated carbon poles. However, the difference was very slight. A like result was obtained when, instead of CO_2, O and the vapor of S were passed into the arc. A continuous stream of S vapor was obtained by attaching to the end of the hollow carbon a glass tube sealed at the lower end and filled with S. A Bunsen burner kept the S boiling vigorously, the vapor passing into the globe and arc through the hollow carbon, which was heated by a second burner to prevent condensation of the vapor before reaching the arc.

It appears that the weight of evidence favors the view that the three bands in question are intimately connected with the presence of N in the arc. But there are reasons for hesitating to accept the conclusion that they are due to cyanogen or to any other compound of C and N. One reason is that the bands are found in the spectrum of the sun. It is difficult to believe that a carbon nitrogen compound exists at so high a temperature, or even at the temperature of the arc. Another reason is that the strength of the bands does not vary much when the quantity of N in the arc is varied.

All the investigations on this subject show that a mere trace of N is sufficient to bring out the cyanogen bands quite clearly while the carbon bands are weak. Flooding the arc with N does not greatly increase the strength of the cyanogen bands or weaken the carbon bands. The following experiment emphasizes this point:

Mercuric cyanide (30 gms.) was placed in a three-bulb combustion tube. One end of the tube was sealed and the other connected by a rubber tube to the hollow carbon of the inclosed arc. The tube was heated by gas burners, and as soon as the cyanogen had displaced all the air in the globe the arc was started. The three cyanogen bands were very slightly, if any, stronger than in the arc in air, and not very much stronger than when treated carbons were used with CO_2 streaming into the arc and globe. Yet the quantity of cyanogen in the arc must have been hundreds of times greater in the first case. That the two spectra should be at all comparable in intensity is not in agreement with our knowledge of spectra in general.

The author inclines to the view that the so-called cyanogen bands are due to carbon in the presence of nitrogen, but not combined with it. It is well known that the spectrum of an element is sometimes greatly changed in the presence of another element, though there be no tendency for the elements to combine. The statement need not be confined to spectra. A very familiar instance is the addition of MnO_2 to $KClO_3$ in the generation of O. The temperature at which the O is given off is greatly reduced, although the MnO_2 does not decompose nor does it combine with the K.

It has been shown that cyanogen is produced by an arc in air or N. However, the compound may be formed in the outer cooler portions of the arc and not in the central hot region, where the cyanogen bands are strongest. The fading out of these bands in the outer regions is more rapid than would be expected if cyanogen were a stable compound in the arc. And to account for their production by a mere trace of N there must be a decided tendency for the compound to form. But experiments show that cyanogen may be decomposed in the arc.

Copper rods were substituted for the carbons of the inclosed lamp. The lower rod was hollow. Cyanogen was passed through it into the arc and globe. The cyanogen bands were strong. The carbon bands at $\lambda = 4737$ and $\lambda = 4382$ appeared as bright as in the inclosed arc between carbon terminals.

It may be urged that the decomposition of the cyanogen was brought about by the presence of Cu. and not by heat alone. If this be true it would seem that the metallic impurities ordinarily present in carbon would prevent the formation of cyanogen in an arc where N was present in traces only.

Many substances besides N appear to affect the spectrum of carbon. Sulphur is an instance. When sulphur vapor was forced into the arc it seemed to tend to equalize the band spectrum, somewhat diminishing the intensity of the lines on the side of the bands next the heads and strengthening the weaker lines on the more refrangible side. The bands were widened until the "grating effect" became continuous in the region of the spectrum photographed. S vapor alone, when forced into an arc between copper poles, gave a faint "grating effect" in the same region.

The Electrolytic Nature of the Electric Arc. By Arthur L. Foley.

[Abstract.]

The spectra of twelve elements were studied to determine the nature of the lines near the carbons and directly between them. The spectrum was obtained by removing the core of one or both of the carbons and replacing it by the salt of the metal to be studied. The salts used were barium carbonate, sodium nitrate, the chlorides of zinc, calcium, strontium, postassium and lithium, the sulphates of chromium, cadmium, and aluminum and the oxides of rubidium and titanium.

Six photographs were taken of the spectrum of each element. The conditions were as follows:

No. I, upper carbon plain (containing no metallic salt) and positive, salt in lower carbon.

No. II, upper carbon plain and negative, salt in lower carbon.

No. III, salt in upper negative carbon, lower carbon plain.

No. IV, salt in upper positive carbon, lower carbon plain.

No. V, salt in both carbons, upper carbon positive.

No. VI, salt in both carbons, lower carbon positive.

The following conclusions were arrived at:

The arc is electrolytic. The electropositive elements seek the negative pole and the electronegative the positive pole. Hence the thickening of the metallic lines at the negative carbon. Convection currents due to heated gases in the arc may be sufficiently strong to mask the true nature of the lines.

In photograph No. IV the Ca lines were as strong at the lower negative carbon as at the upper positive carbon, which contained the salt. In No. III 47 Ca lines appeared at the upper negative carbon and only 14 at the lower positive pole. The 14 were not due to the salt contained in the upper pole, but to impurities in the loewr carbon, for they were present when a plain carbon was substituted for the one containing the salt. The Ca traveled with, but not against, the current.

Ca photographs were chosen to illustrate the above effects because they represent about an average for the elements experimented upon. Ti did not show the effects at all. The ines extended across the spectrum with almost uniform intensity. Sometimes they were slightly intensified at the positive carbon, probably because of the higher temperature.

The Zn lines were slightly stronger at the negative carbon. The lines of Rb, K, Na, Li, Ba and Sr showed a much more decided preference for the negative pole than did the Ca lines. The preference was most marked in the case of Rb, though the most striking photographs were obtained with Ba, which has a large number of strong lines in this region of the spectrum.

As far as it could be determined the order of the elements, as regards the tendency of their spectral lines to cling to the negative carbon, is the same as their order in the electropositive-negative series.

The following experiment is more conclusive: The negative carbon of a horizontal arc was filled with calcium chloride. A new plain carbon formed the positive pole. A horizontal arc was used, otherwise the heat convection currents might have thrown doubt upon the results of the experiment. The slit was horizontal and extended from pole to pole. The carbons were placed one cm. apart and an arc was formed by passing between them a third carbon, which served to bring the poles in momentary contact. After one minute the current was shut off, and the carbon containing the Ca was replaced by a new plain carbon. The arc was then formed again by means of a third carbon, and the spectrum was photographed. No Ca lines appeared except those always present in the ordinary arc.

In the second part of the experiment a plain carbon was used as a negative pole, and the Ca was placed in the positive pole. The arc was formed as before and allowed to continue for one minute. The positive pole containing the Ca was then replaced by a new plain carbon, the arc was formed and the spectrum photographed. The Ca lines came out very clear and strong, almost as strong as if the negative carbon had been filled with the salt. There can be but one conclusion. In the first case the Ca was in the negative pole, and there was no tendency for it to pass over to the positive pole. In the second case it was placed in the positive pole, and it freely passed over to the plain negative pole. The latter became so impregnated with it that it was capable of giving a strong spectrum of Ca when it was afterwards used in an arc with a plain carbon.

Any of the elements, which show a marked tendency to cling to the negative pole, may be used instead of Ca in the above experiment. The result was doubtful in the case of Zn.

The electrolytic nature of the arc was further confirmed by a series of measurements of the voltage necessary to maintain an arc of given length between unlike electrodes. It was found that a much higher voltage was required when the metallic salt was placed in the negative pole than was necessary when the salt was in the positive pole.

When Ca was placed in the upper pole only and it was made positive, the average of several readings gave 49 volts between the upper and lower carbons. With the same length of arc and the current reversed in direction the average reading was 65 volts. With a slightly shorter arc the readings were 35 and 48 volts, respectively. With the salt in the positive carbon of a horizontal arc the reading was 34 volts, and when in the negative carbon, 45 volts.

Similar results were obtained when Li and K were used instead of Ca.

An arc was formed between a carbon and a copper rod of the same size and shape. An average of many readings showed that about 10 volts more were required to maintain an arc with the current from the carbon to the copper rod than were required when the current was reversed.

When a third carbon was held with its point midway between the poles and in an arc maintained at 55 volts, the potential difference between it and the negative carbon was about 15 volts and between it and the positive carbon about 40 volts. The introduction of Ca or K into the negative carbon did not change the voltage between it and the third carbon. When the salt was introduced into the positive pole the voltage between the positive pole and the third carbon fell to 25 volts, but the voltage between the negative and third carbons remained 15. It appears that the current passes from pole to pole, in part, at least, as a convective discharge of charged particles.

NOTE ON CHARLES SMITH'S DEFINITION OF MULTIPLICATION. BY ROBERT J. ALEY.

"To multiply one number by a second is to do to the first what is done to unity to obtain the second."

This definition covers the multiplication of positive and negative integers, fractions and imaginary numbers. Accepting it as true, the law of signs follows as a result. We can easily show that it includes the multiplication of imaginaries. Suppose we are to multiply a by $b\,i$. We are to do to a what is done to unity to obtain $b\,i$. To obtain $b\,i$ from unity we take unity b times and turn it counter clock-wise through an angle of 90 degrees. By performing this operation upon a we obtain $ab\,i$. Suppose we are to multiply $a\,i$ by $b\,i$. By the same process as above we ıeadily see that the result is $-ab$. This shows that the definition includes practically all of Quaternion multiplication.

If we undertake to apply it to the multiplication of b by a^2 we encounter our first difficulty. a^2 has been obtained from unity by taking unity a times and squaring. If we do this to b we obtain $a^2\,b^2$, a result manifestly wrong. If, however, we remember that $a=a\,a$ and is obtained from unity by taking it $a\,a$ times, our difficulty disappears and we obtain the correct result $a^2\,b$. If we undertake to multiply b by $a^{1/2}$ we find a difficulty which seems to be insurmountable. The only way we can obtain $a^{1/2}$ from unity is by taking unity a times and extracting the square root. If we do this to b we obtain the incorrect product $a^{1/2}\,b^{1/2}$. The definition seems to fail utterly when applied to irrationals. Perhaps, after all, it is better to follow the custom of most algebras and make only symbolic definitions.

INDIANA UNIVERSITY, December 8, 1897.

Collinear Sets of Three Points Connected With the Triangle. By Robert J. Aley.

This paper does not claim to be either original or complete. It contains a fairly complete list of collinear sets connected with the triangle. All cases of collinearity connected with polygons of more than three sides have been omitted.

The subject of collinearity is both interesting and fruitful. There are three well defined methods of proving the collinearity of three points. The classic one is the application of the theorem of Menelaus: "If D, E, F are points on the sides B C, C A, AB respectfully of AB C, such that $BD \times CE \times AF = -DC \times EA \times FB$, then D, E, F are collinear." In many cases the data are insufficient for the use of this method. Another method of frequent use is to prove that the angle formed by the three points is a straight angle. The author has used another method, believed to be original with him, when the points in question are such that the ratios of their distances from the sides can be determined. This method is fully illustrated in "Contributions to the Geometry of the Triangle."

Collinear problems fall into two very well marked classes. The first class is made up of those points which are definitely located with respect to the triangle. The second class is made up of those points which are located with reference to some auxiliary point.

NOTATION.

In order to save time in the enunciation of propositions the following notation will be used:

A B C is the fundamental triangle.

A_1 B_1 C_1 is Brocard's first triangle.

M_a M_b M_c is the triangle formed by joining the middle points of the sides of AB C.

M_{1a} M_{1b} M_{1c} is the triangle formed by joining the middle points of the sides of A_1 B_1 C_1.

M is the centre of the circumcircle of AB C.

M^1 is the point isotomic conjugate to M.

G is the median point or Centroid of AB C.

K is Grebe's point or the Symmedian point.

D is the centre of perspective of AB C and A_1 B_1 C_1.

D^1 is the point isogonal conjugate to D.

H is the Orthocentre.

Ω and Ω^1 are the two Brocard points.

N is Tarry's point.

Q is Nagel's point. (It is the point of concurrency of the three lines joining the vertices to the points of tangency of the three escribed circles.)

Q^1 is the isotomic conjugate of Q.

O is the centre of the inscribed circle.

S is the point of perspective of M_a M_b M_c and M_{1a} M_{1b} M_{1c}.

S^1 is the point isogonal conjugate to S.

R is the point of concurrence of perpendiculars from A, B, C on the sides of Nagel's triangle.

M_1 is the centre of Nagel's circle.

T is the point of concurrence of perpendiculars from A′ B′ C′ upon the respective sides of A″ B″ C″.

Z is Brocard's centre.

Z^1 is the point isogonal conjugate to Z.

P is the point isotomic conjugate to O.

P^1 is the point isogonal conjugate to P.

Q_1 is the point isogonal conjugate to Q^1.

F is the centre of Nine points circle.

THEOREMS.

The original sources of the theorems are known in only a very few cases. The references simply indicate where the theorems may be found.

(1.) M, H and G are collinear.

(Lachlan—Modern Pure Geometry, p. 67.)

(2.) K, G and the Symmedian point of M_a M_b M_c are collinear.

(Ibid, p. 138.)

(3.) Tangents to the circumcircle at the vertices of A B C form the triange P Q R; H_a, H_b, H_c are the feet of the altitudes of AB C; P H_a, QH_b, RH_c are concurrent in a point which is collinear with M and H.

(Ibid, p. 138.)

(4.) M, K and the orthocentre of its pedal triangle are collinear.

(McClellan—The Geometry of the Circle, p. 83.)

(5) M and the orthocentre of its pedal triangle are equidistant from and collinear, with the centre of Taylor's Circle.

(Ibid, p. 83.)

(6.) Q, Q^1 and P are collinear.

(Aley—Contributions to the Geometry of the Triangle, p. 8.)

(7.) K, P^1 and Q_1 are collinear.

(Ibid, p. 13.)

(8.) S^1, K and D are collinear.

(Ibid, p. 15.)

(9.) H, M^1 and D are collinear.

(Ibid, p. 19.)

(10.) Z^1, F and D are collinear.

(Ibid, p. 24.)

(11.) Ω, Ω^1 and S are collinear.

(Schwatt—Geometric Treatment of Curves, p 7.)

(12.) K, Z, M are all collinear.

(Ibid, p. 3.)

(13.) Z^1, H, and S are collinear.

(Ibid, p. 13.)

(14.) N, M, and D are collinear.

(Ibid, p. 17.)

(15.) D, S and G are collinear.

(Ibid, p. 7.)

(16.) Q, O and G are collinear.

(Ibid, p. 36.)

(17.) D^1, H and N are collinear.

(Ibid, p. 16.)

(18.) Q, M and Z are collinear.

(Ibid, p. 44.)

(19.) R, O and M_1 are collinear.

(Ibid, p. 43.)

(20.) M_c, M_{1c} and S are collinear.

(Casey—Sequel, 5th edition, p. 242.)

(21.) K, M and the center of the triplicate ratio circle are collinear.

(Richardson and Ramsey—Modern Plane Geometry, p. 41.)

(22.) N, M and the point of concurrence of lines through A, B, C parallel to the corresponding sides of Brocard's first triangle are collinear.

(Lachlan—Modern Pure Geometry, p. 81.)

(23.) K, M_a and the middle point of altitude upon B C are collinear.

(Richardson and Ramsey—Modern Plane Geometry, p. 58.)

(24.) H, G and F are collinear.

(W. B. Smith—Modern Synthetic Geometry, p. 141.)

(25.) If A^1 is the pole of B C with respect to the circumcircle of A B C, then A_1, A and the Symmedian point are collinear.

(Casey—Sequel, 5th edition, p. 171.)

(26.) The intersections of the anti-parallel chords D^1 E, E^1 F, F^1 D with Lemoine's parallels D E^1, E F^1, F D^1 respectively, are collinear. The D, E, F, D^1, E^1, F^1, are the six points of intersection of Lemoine's circle with the sides of the triangle.

(Ibid, p. 182.)

(27.) If the line joining two corresponding points of directly similar figures F_1, F_2, F_3 described on the sides of the triangle AB C, pass through the centroid, the three corresponding points are collinear.

(Ibid, p. 237.)

(28.) If from Tarry's point _|_'s be drawn to the sides B C, C A, A B of the triangle, meeting the sides in $(\alpha, \alpha_1, \alpha_2)$ $(\beta, \beta_1, \beta_2)$ $(\gamma, \gamma_1, \gamma_2)$, the points α, β, γ are collinear, so also $(\alpha_1, \beta_2, \gamma)$ and $(\alpha_2, \beta, \gamma_1)$. (Neuberg.)

(Ibid, p. 241.)

(29.) In any triangle AB C, O, O^1 are the centres of the inscribed circle and of the escribed circle opposite A; O O^1 meets B C in D. Any straight line through D meets AB, AC respectively in b, c. O b, O^1 c intersect in P, O^1b, O c in Q. P A Q is a straight line perpendicular to O O^1.

(Wolstenholme—Math. Problems, p. 8, No. 79.)

(30.) A triangle P Q R circumscribes a circle. A second triangle A B C is formed by taking points on the sides of this triangle such that A P, B Q, C R are concurrent. From the points A, B, C tangents A a, B b, C c are drawn to the circle. These tangents produced intersect the sides B C, C A, AB, in the three points a b c, which are collinear.

(Catalan Geométrie Elementáire, p. 250.)

(31.) The three internal and three external bisectors of the angles of a triangle meet the opposite sides in six points which lie three by three in four straight lines.

(Richardson and Ramsey—Modern Plane Geometry, p. 19.)

(32.) If O be any point, then the external bisectors of the angles B O C, C O A, A O B meet the sides B C, C A, A B respectively in three collinear points.

(Ibid, p. 52.)

(33.) The external bisectors of the angles of a triangle meet the opposite sides in collinear points. (A special case of 31.)

(Lachlan—Modern Pure Geometry, p. 57.)

(34.) Lines drawn through any point O perpendicular to the lines O A, O B, O C meet the sides of the triangle AB C in three collinear points.

(Ibid, p. 59.)

(35.) If any line cuts the sides of a triangle in X, Y, Z; the isogonal conjugates of A X, B Y, C Z respectively will meet the opposite sides in collinear points.

(Ibid, p. 59.)

(36.) If a line cut the sides in X, Y, Z; the isotomic points of X, Y, Z with respect to the sides will be collinear.

(Ibid, p. 59.)

(37.) If from any point P on the circumcircle of the triangle AB C, P L, P M, P N be drawn perpendicular to P A, P B, P C, meeting B C, C A, AB, in L, M, N, then these points L, M, N are collinear with circumcentre.

(Ibid, p. 67.)

(38.) If P L, P M, P N be ⊥'s drawn from a point P on the circumcircle to the sides B C, C A, AB respectively, and if Pl, Pm, Pn be drawn meeting the sides in l, m, n and making the angles L Pl, M Pm, N Pn equal when measured in the same sense, then the points l, m, n are collinear.

(Ibid, p. 68.)

(39.) If X Y Z and X^1 Y^1 Z^1 are any two transversals of the triangle AB C: Y Z'; Z X^1, X Y^1 cut the sides B C, C A, AB in collinear points.

(Ibid, p. 60.)

(40.) If X Y Z and X^1 Y^1 Z^1 be any two transversals of the triangle AB C, and and if Y Z^1, Y^1 Z meet in P, Z X^1, Z^1 X meet in Q, X Y^1, X^1 Y in R, then A P, B Q, C R cut the sides B C, C A, AB in collinear points.

(Ibid, p. 61.)

(41.) If the lines AO, BO, CO cut the sides of the triangle AB C in X, Y, Z; and if the points X^1, Y^1, Z^1 be the harmonic conjugate points of X, Y, Z with respect to B, C; C, A; and A, B, respectively, then X^1, Y^1, Z^1 are collinear.

(Ibid, p. 61.)

(42.) If the inscribed circle touch the sides in X, Y, Z, then the lines Y Z, Z X, X Y cut the sides B C, C A, AB in three collinear points.

(Ibid, p. 62.)

(43.) The feet of perpendiculars from H and G upon A G and A H respectively are collinear with K.

(Ibid, p. 147.)

(44.) If three triangles AB C, A_1 B_1 C_1, and A_2 B_2 C_2 have a common axis of perspective, their centres of perspective when taken two and two, are collinear.

(McClellan—Geometry of the Circle, p. 122.)

(45.) ABC is a triangle inscribed in and in perspective with $A^1 B^1 C^1$; the tangents from ABC to the incircle of $A^1 B^1 C^1$ meet the opposite sides in three collinear points, X, Y, Z (B C in X, etc.).

(Ibid, p. 128.)

(46.) If three pairs of tangents drawn from the vertices of a triangle to any circle, meet the opposite sides X, X^1, Y, Y^1, Z, Z^1, and if X, Y, Z are collinear, so also are X^1, Y^1, Z^1.

(Ibid, p. 128.)

(47.) If X Y Z is a transversal and if X^1, Y^1 Z^1 are the harmonic conjugates of X, Y, Z, then

Y^1, Z^1, X; Z^1 X^1, Y; X^1, Y^1, Z are collinear.

Also the middle points of XX^1, YY^1, ZZ^1 are collinear.

(Ibid, p. 131.)

(48.) If L is an axis of symmetry to the congruent triangles A B C and $A^1 B^1 C^1$ and O is any point on L, $A^1 O$, $B^1 O$, $C^1 O$ cut the sides B C, C A, AB in three collinear points.

(Depuis—Modern Synthetic Geometry, p. 204.)

(49.) Two triangles which have their vertices connecting concurrently, have their corresponding sides intersecting collinearly.

(Desargue's Theorem.) (Ibid, p. 204.)

(50.) A^1, B^1, C^1 are points on sides of AB C such that AA^1, BB^1, CC^1 are concurrent, then AB, $A^1 B^1$; B C, $B^1 C^1$, C A, $C^1 A^1$ meet in three points Z, X, Y which are collinear.

(Ibid, p. 205.)

(51.) If P be any point, AB C a triangle and $A^1 B^1 C^1$ its polar reciprocal with respect to a polar centre O, the perpendiculars from O on the joins P A, P B, and P C intersect the sides of $A^1 B^1 C^1$ collinearly.

(Ibid, p. 223.)

(52.) If the three vertices of a triangle be reflected with respect to any line, the three lines connecting the reflexions with any point on the line intersect collinearly with the opposite sides.

(Townsend—Modern Geometry, p. 180.)

(53.) When three of the six tangents to a circle from three vertices of a triangle intersect collinearly with the opposite sides, the remaining three also intersect collinearly with the opposite sides.

(Ibid, p. 180.)

(54.) If from the middle points of the sides of the triangle A B C, tangents be drawn to the corresponding Neuberg circles, the points of contact lie on two right lines through the centroid of A B C.

(Casey—Sequel, p. 241.)

(55.) If P is a Simson's point for A B C, and O any other point on the circumcircle of A B C, then the projections of O upon the Simson's lines of O with respect to the triangles P A C, P B C, P C A, A B C are collinear.

(Lachlan—Modern Pure Geometry, p. 69.)

(56.) When three lines through the vertices of a triangle are concurrent, the six bisectors of the three angles they determine intersect the corresponding sides of the triangle at six points, every three of which on different sides are collinear if an odd number is external.

(Ibid, p. 181.)

(57.) When three points on the sides of a triangle are collinear, the six bisections of the three segments they determine connect with the corresponding vertices of the triangle by six lines, every three of which through different vertices are collinearly intersectant with the opposite sides if an odd number is external.

(Ibid, p. 182.)

(58.) A_1, M_{1a} and K^1, the intersection of the Symmedian through A and the tangent to circumcircle at C, are collinear.

(Schwatt—Geometric Treatment of Curves, p. 4.)

(59.) If M X and F Y are parallel radii, in the same direction, in circumcircle and Feuerbach circle, then X, Y, and H are collinear.

(Ibid, p. 21.)

(60.) If Y_1 is the other extremity of the diameter F Y, then Y_1, G, and X are collinear.

(Ibid, p. 21.)

(61.) If P, a point on the circumcircle of A B C be joined with H^1, H^{11}, H^{111}, the respective intersections of the produced altitudes with circumcircle, and if the points of intersection of P H^1, P H^{11}, P H^{111} with B C, C A, AB be U, V, W respectively, then U, V, W are collinear.

(Ibid, p. 23.)

(62.) A O, B O, C O meet the circumcircle in A^1, B^1, C^1; perpendiculars from M upon the sides B C, C A, AB meet Nagel's circle in A^{11}, B^{11}, C^{11}; the corresponding sides of $A^1 B^1 C^1$ and $A^{11} B^{11} C^{11}$ meet in three collinear points.

(Ibid, p. 40.)

(63.) The feet of the perpendiculars on the sides of a triangle from any point in the circumference of the circumcircle are collinear. (Simson's line.)

(64.) If two triangles are in perspective the intersections of the corresponding sides are collinear. A different statement of 49.

(Mulcahy—Modern Geometry, p. 23.)

(65.) The perpendiculars to the bisectors of the angles of a triangle at their middle points meet the sides opposite those angles in three points which are collinear.

(G. DeLong Champs.) (Mackay, Euclid, p. 356.)

I, I_1, I_2, I_3 are the centres of the inscribed and three escribed circles of the triangle A B C. D, E, F; D_1, E_1, F_1; D_2, E_2, F_2; D_3; E_3; F_3: are the feet of the perpendiculars from these centres upon the respective sides. N, P, Q are the feet of the bisectors of the angles A, B, C.

(66.) A B, D E, D_2 E_1 concur at Q_1.
B C, E F, E_3 F_2 concur at N_1.
C A, F D, F_1 D_3 concur at P_1.
Q_1, N_1, and P_1 are collinear.

(67.) A B, D_1 E_2, D_3 E_3 concur at Q_2.
B C, E_2 F_3, E_1 F_1 concur at N_2.
C A, F_3 D_1, F_2 D_2 concur at P_2.
Q_2, N_2, and P_2 are collinear.

(68.) A B, N P, I_1 I_2 concur at Q_3.
B C, P Q, I_2 I_3 concur at N_3.
C A, Q N, I_3 I_1 concur at P_3.
Q_3 N_3 and P_3 are collinear.

(66, 67, 68—Stephen Watson in Lady's and Gentleman's Diary for 1867, p, 72. Mackay, Euclid, p. 357.)

(69.) M_a, the middle point of Q O and the middle point of Q A are collinear.

(Mackay, Euclid, p. 363.)

(70.) The six lines joining two and two the centres of the four circles touching the sides of the triangle A B C, pass each through a vertex of the triangle.

(Mackay, Euclid, p. 252.)

(71.) M_a, O, and the middle of the line drawn from the vertex to the point of inscribed contact on the base are collinear. A similar property holds for the escribed centres.

(Mackay, Euclid, p. 360.)

Indiana University,
December 18, 1898.

On the Reduction of Irrational Algebraic Integrals to Rational Algebraic Integrals. By John B. Faught.

The Inverse operations of Analysis are more interesting and fruitful than the Direct, since each demands a new field of quantity or a new kind of function in order that it may be possible without exception. Thus negative numbers have their origin in subtraction, fractions grow out of division, and irrational and imaginary numbers arise in the extraction of roots. The same thing is true of integration considered as the inverse of differentiation.

At the time of the discovery of the Calculus the algebraic and certain elementary transcendental functions were known. The algebraic functions included all those expressions which can be formed by a finite combination of the processes of addition, subtraction, multiplication, division, involution and the extraction of roots. The transcendental functions included the exponential, logarithmic, trigonometric and circular functions. These will be called the elementary functions, and exclude the infinite series.

It is a fundamental theorem of the Integral Calculus that the integral of any rational algebraic function can be expressed in terms of the elementary functions. This is sometimes expressed by saying that any rational algebraic function can be integrated.

The attention of mathematicians was early directed to those integrals that are made irrational by the presence of the square or other root of a polynomial of the first, second and higher degrees. It was soon found that if the irrationality was due to a square root of a polynomial of the first or second degree the integral could be expressed in terms of the elementary function. The integration being accomplished in each case by reducing the irrational function to a rational function and then performing the integration. This method, however, was found to fail, in general, as soon as the polynomial under the radical is of the third or higher degree. The investigation of irrational algebraic integrals led to the discovery of the Abelian functions of which the Hyperelliptic and Elliptic functions are special cases. By means of these functions the integral of any algebraic function can be expressed.

The integrals under consideration here are known as Abelian Integrals and are defined thus:

$$\int F(x, y)\, dx.$$

where y is defined by:

$$f_n(x, y) = o,$$

and F denotes a rational function of x and y.

If y is expressed as an explicit function of x, the expression will contain, in general, a root of some polynomial. The definition is sometimes stated as follows:

$$\int F(x, y)\, dx,$$
$$y = \sqrt[m]{R_n(x)}.$$

Byerly (Integral Calculus Ch. VI) observes that "very few forms (of the above type) are integrable, and most of these have to be rationalized by ingenious substitutions." It is the purpose of this paper to determine the conditions under which irrational algebraic integrals can be reduced to rational algebraic integrals and to present a method of obtaining a substitution by which the integral is rationalized.

Given then, the integral:

$$\int F(x, y)\, dx.$$
$$f_n(x, y) = o,$$

where F is a rational function, to determine the conditions under which this integral can be reduced to the integral:

$$\int r(\lambda)\, d\lambda.$$

where r is a rational function.

Let us consider in the first place the integral:

$$\int F(x, y)\, dx.$$
$$y = \sqrt{R(x)}$$

where $R(x)$ is a polynomial of the second degree.

The equation:

(1.) $\quad y^2 - R(x) = o$

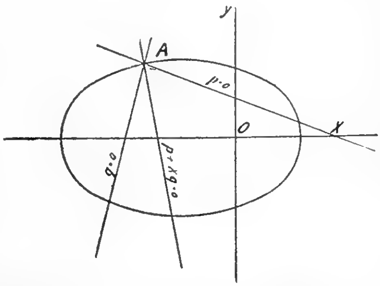
is of the second degree and hence represents a conic section. Let A be any point on the curve and let

(2.) $\quad p = o, \; q = o,$

be the equations of any two lines through A. Then

(3.) $\quad p + \lambda q = o,$

represents any line L through A. Since



this equation is linear in x and y it can be solved for y by rational processes. Let the solution be:

(4.) $$y = \phi(x, \lambda).$$

(5.) $$\therefore y^2 = \phi^2(x, \lambda).$$

(6.) $$\therefore \phi^2(x, \lambda) - R(x) = o.$$

This is the equation for the determination of the points of intersection of L and the conic. One solution is known, viz.: $x = x_a$. Hence $x - x_a$ is a factor. Divide by $x - x_a$ and call the resulting equation:

(7.) $$X(x, \lambda) = o.$$

This equation is linear in x and therefore can be solved for x by rational processes. Let the solution be:

(8.) $$x = \psi(\lambda).$$

(9.) $$\therefore y = \phi[\psi(\lambda)].$$

(10.) $$dx = \psi'(\lambda)\, d\lambda.$$

(11.) $$\therefore \int F(x, y)\, dx = \int F\left\{\psi(\lambda), \phi[\psi(\lambda)]\right\}\psi'(\lambda)\, d\lambda.$$

Since F, ϕ, ψ, ψ' are all rational functions, it follows that

$$F\left\{\psi(\lambda), \phi[\psi(\lambda)]\right\}\psi'(\lambda).$$

is a rational function of λ. Call this function r (λ).

(12.) $$\therefore \int F(x, y)\, dx = \int r(\lambda)\, d\lambda.$$

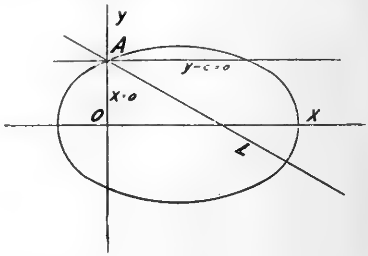
As an illustration consider the integral:

$$\int F(x, y)\, dx,$$

$$y = \sqrt{ax^2 + bx + c^2}.$$

(1.) $$y^2 = ax^2 + bx + c^2.$$

Take A as the point (o, c)



and as the lines through A:

(2.) $$y = c,\ x = o.$$

Then the equation of L is:

(3.) $$y - c + \lambda x = o.$$

(4.) $$\therefore y = \phi(x, \lambda) = c - \lambda x.$$

(5.) $$\therefore y^2 = (c - \lambda x)^2.$$

(6.) $$(c - \lambda x)^2 - (ax^2 + bx + c^2) = o.$$

(7.) $$\therefore X(x, \lambda) \equiv (\lambda^2 - a)\, x - (2c\lambda + b) = o.$$

(8.) $$\therefore x \equiv \psi(\lambda) = \frac{2c\lambda + b}{\lambda^2 - a}$$

(9.) $$y \equiv \phi[\psi(\lambda)] = \frac{c\lambda^2 + b\lambda + ac}{a - \lambda^2}.$$

(10.) $$dx \equiv \psi'(\lambda)\, d\lambda = 2\, \frac{c\lambda^2 + b\lambda + ca}{(a - \lambda^2)^2}\, d\lambda.$$

(11.) $$\int F(x, y)\, dx = 2 \int F\left(\frac{2c\lambda + b}{\lambda^2 - a},\ \frac{c\lambda^2 + b\lambda + ca}{a - \lambda^2}\right). \ \frac{c\lambda^2 + b\lambda + ca}{(a - \lambda^2)^2}\, d\lambda.$$

(12.) $$\therefore \int F(x, y)\, dx = \int r(\lambda)\, d\lambda.$$

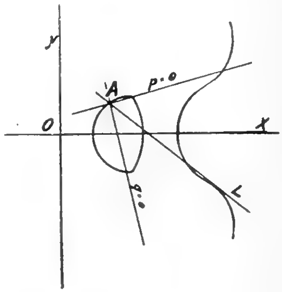
In particular:

$$\int \frac{dx}{\sqrt{ax^2 + bx + c^2}} = -2 \int \frac{d\lambda}{a - \lambda^2}.$$

This method always furnishes the substitution by which the reduction is effected, viz.: $x = \frac{2c\lambda + b}{\lambda^2 - a}$.

Consider next the integral:

$$\int F(x, y)\, dx$$
$$y = \sqrt{ax^3 + bx^2 + cx + d}.$$



(1.) $$y^2 = ax^3 + bx^2 + cx + d.$$
(2.) $$p = o,\ q = o.$$
(3.) $$p + \lambda q = o.$$
(4.) $$y = \phi(x, \lambda)$$
(5.) $$\phi^2(x, \lambda) - (ax^3 + bx^2 + cx + \phi) = o.$$
(6.) $$X(x, \lambda) \equiv \frac{\phi^2(x, \lambda) - (ax^3 + bx^2 + cx + d)}{x - x_a} = o.$$

Now the equation:

$$X(x, \lambda) = o.$$

is of the second degree in x and hence can not in general be solved by rational processes. The necessary and sufficient condition for the reduction of the given integral to a rational integral is that the coordinates of at least one point of intersection of L and the cubic:

$$f_3 \equiv y^2 - (ax^3 + bx^2 + cx + d) = o.$$

be expressible rationally in terms of λ. This will certainly be true if the cubic, $f_3 = o$, has a double point. For taking A at the double point two solutions of the equation:

$$\phi^2(x\lambda) - (ax^3 + bx^2 + cx + d) = o.$$

are known, and, after dividing by $(x - x_a)^2$, the equation:

$$X(x, \lambda) = o.$$

is a linear equation, and can be solved by rational processes.

If now the cubic, $f_3 = o$, has a double point, then the first polar:

$$D f_3 \equiv o^*$$

that is: $\frac{d f_3}{d x'} = o, \frac{d f_3}{d y'} = o, \frac{d f_3}{d z'} = o,$

where f_3 has been made homogeneous by the introduction of the variable z.

If $f_3 = o$ has a double point then the curve is a unicursal or rational curve. Indeed, if one solution of $X(x, \lambda) = o$ is rational, the other must also be rational, and hence the cubic, $f_3' = o$, is unicursal, and hence it must have a double point, since its deficiency is zero.

Theorem: The integral:

$$\int F(x, y)\, dx$$
$$y = \sqrt{R_3(x)},$$

can be reduced to a rational integral only when the cubic:

$$f_3 \equiv y^2 - R_3(x) = o$$

is a unicursal curve.

Consider next the general integral:

$$\int F(x, y)\, dx$$
$$y = \sqrt[m]{R_n(x)},\ m \leqq n.$$

The curve:

$$f_n \equiv y^m - R_n(x) = o$$

is of the n^{th} order, and the equation:

$$X(x, \lambda) = o$$

is of the $(n-1)^{st}$ degree. If one rational solution of this equation can be found the reduction can be made, otherwise not.

Suppose the curve: $f_n = o$, has a multiple point of order k, then, by taking A at this point, the equation

$$X(x, \lambda) = o$$

is of degree (n–k). In this case it is necessary to find a rational solution of an equation of the $(n-k)^{th}$ degree. Now $f_n = o$, has a multiple point of orner k if the $(k-1)^{st}$ polar of that point vanishes identically.

$$D^{k-1} f_n \equiv o.$$

If $f_n = o$ has a multiple point of order (n–1), that is if:

$$D^{n-2} f_n \equiv o,$$

then the equation:

$$X(x, \lambda) = o,$$

is linear and the reduction is always possible.

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* Clebsch. Vorlesungen über Geometrie. Vol. I, p. 315.

As an illustration, consider the integral:

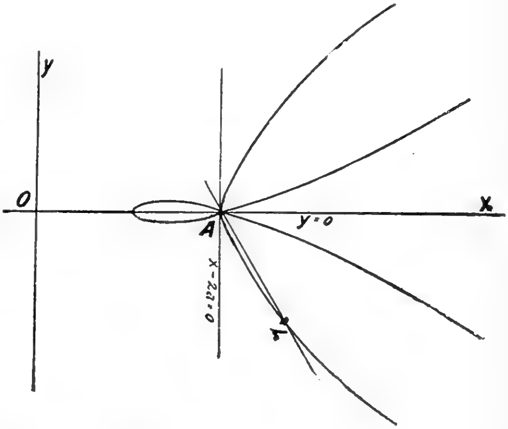
$$\int F(x, y)\, dx.$$

$$y = \sqrt{[(x-a) + \sqrt{a(x-a)}](x-2a)}.$$

Here we have:

(1.) $f_4 \equiv y^4 - 2y_2(x-a)(x-2a) + (x-a)(x-2a)^3 = o,$

and this curve has a triple point at $(2a, o)$. Taking A at this point, and



(2.) $y = o,\ x - 2a = o$

as the equations of lines through A, we are to solve for the intersections of $f_4 = o$, and the line:

(3.) $y + \lambda(x - 2a) = o.$

Since three solutions are known, we readily find:

(7.) $X(x, \lambda) \equiv x(\lambda^2 - 1)^2 - a(2\lambda^4 - 2\lambda^2 + 1) = o.$

(8.) $\therefore x = \dfrac{a(2\lambda^4 - 2\lambda^2 + 1)}{(\lambda^2 - 1)^2}.$

(9.) $\therefore y = -\lambda(x - 2a) = -\dfrac{a\lambda(2\lambda^2 - 1)}{(\lambda^2 - 1)^2}.$

If the curve $)f_n = o$, instead of having a multiple point of order $(n-1)$, has $\frac{1}{2}(n-1)(n-2)$ double points, that is, if its deficiency is zero, then it is a unicursal curve, and hence x and y can be expressed rationally in terms of a single parameter, and hence the reduction can be performed.

Alternate Processes. By Professor Arthur S. Hathaway.

I. Introduction.

1. The alternate (and symmetric) processess that we develop seem valuable from their simplicity and power, and their general applicability in all departments of mathematics. They may be employed in any algebra in which addition is associative and commutative without regard to the laws of multiplication.

2. The notation is a doubly dual one, *i. e.*, from a given theorem and proof a dual theorem and proof may be derived by correspondence, and each of these has its dual by another correspondence, so that every theorem is of four-fold interpretation.

3. As illustrative applications we have taken the extensions, to n-fold algebra, of Green's theorem connecting integration through a space with integration over the boundary of that space (the laws of multiplication undetermined); the theory of determinants in any algebra; quaternions, and four-fold space.

4. The alternate processes lead in quaternions to formulas that are almost identical with those of Prof. Shaw's "A Processes," and the two notations are readily convertible. The advantages of our notation are that it pertains to a general theory and that its developments are easy and natural rather than arbitrary and labored.

II. DEFINITIONS.

5. We consider a function, $\phi(p_1, p_2, \ldots p_n)$, of n variables, and substitutions, s, s', *etc.*, that permute these variables among themselves.

6. We let (s) stand for the assemblage $(s_1, s_2, \ldots s_m)$, (s'), stand for $(s_1', s_2', \ldots s'_{m'})$, and $(t) = (s)(s')$, stand for $(t_1, t_2, \ldots t_{mm'})$, where $t_u s = _r s'_{r'}$, $r = 1, 2, \ldots m$, $r' = 1, 2, \ldots m'$, and $u = m'(r-1) + r'$, say.

7. We further denote, by $\pm s$, the substitution s, with the factor *1* or -1, according as s involves an even or an odd number of transpositions, and by $e_{(s)}$, the fraction which is the ratio of the excess of the number of positive over the number of negative substitutions in (s) to the whole number of substitutions in (s). When (s) forms a "group" we have $e_{(s)} = 1, -1$, or 0, the latter value in all cases where the group contains both positive and negative substitutions.

8. We denote by $A_{(s)}$, the *alternate process*, $\frac{1}{m}\sum_{r=1}^{r=m} \pm s_r$. This process performed on any operand ϕ before which it is placed, gives as a result a sum of terms, $\Sigma \pm \phi_{s_r}$, divided by the number of terms in the sum, where ϕ_{s_r} is the function ϕ with its variables rearranged by the substitution s_r.

9. When (s) includes all substitutions of the n variables, so that $m = \underline{|n}$, the corresponding process is denoted by A. When a process pertains to the group of $\underline{|m}$ substitution of m given variables (m not $= n$), it is denoted by $\tilde{A}$ with the affected variables correspondingly marked.

10. A function ϕ is *alternate as to* (s) when $\pm s_r \cdot \phi = \phi$, $r = 1, 2, \ldots m$.

11. A function ϕ is *alternate as to* (s) *for the arrangements* (s') when every $\phi_{s'r'}$ is alternate as to (s).

12. We distinguish between $s_r \cdot \phi = \phi_{sr}$ and $\cdot\, s_r\, \phi$; *viz.*, the latter function involves the symbol s_r which is a function of the variables so that a substitution on the variables of $\cdot\, s_r \phi$, which have the same order as in ϕ, is not equal to the same substitution on ϕ_{sr}. In fact $s \cdot s_r\, \phi = s_r\, \phi_s = s_r\, s \cdot \phi$.

13. We have also symmetric processes, $C_{(s)}$, *symmetric functions as to* (s), *etc.*, whose definitions are obtained by replacing $\pm s_r$ by s_r in the above definitions. There is a dualty between "alternate" and "symmetric" which consists in the interchange of corresponding terms. The fraction $e_{(s)}$ is in general its own dual.

14. There is also a dual interpretation of the substitution s, *viz.*, write for the moment $\phi\,(p_1, p_2, \cdot \cdot p_n) = \phi \begin{smallmatrix} 1, & 2, & \cdot\,\cdot & n \\ 1, & 2, & \cdot\,\cdot & n, \end{smallmatrix}$ where we have the number of a "variable," and beneath it, the number of its "place" in ϕ. Ordinary substitutions affect the upper line of numbers only, *i. e.*, the "variables." The same substitutions on the lower line of numbers only are "place" substitutions. The substitution s that affects the given number *1, 2, . . . n* may be marked $\frown{s}$ or $\underset{\smile}{s}$ according as it affects variable or place numbers. The dualty arises from these two interpretations of the substitutions of any process. When the variables of the operand that are affected by $\overset{\frown}{s}$ occupy the places corresponding to their numbers, we have $\underset{\smile}{s} = \overset{\frown}{s}^{-1}$, and the processes $\tilde{A}_{(s)}$, $\underset{\smile}{A}_{(s)}$ give the same result provided (s) is a substitution group. If, however, the above arrangement of the variables be affected by a substitution s', and the result taken as operand, we have $\underset{\smile}{s} = \overset{\frown}{s'}\, \overset{\frown}{s}^{-1}\, \overset{\frown}{s'}^{-1}$, so that the two processes $\tilde{A}$, $\underset{\smile}{A}$ to the same group (s) are in general different, the latter being equivalent to the former to a group that is similar to (s) only.

III. THEOREMS.

[The proofs are too elementary to need insertion.]

Theor. 1. If ϕ be alternate (or symmetric) as to (s), then is $A_{(s)}\ \phi = \phi$ (*or* $e_{(s)}\ \phi$).

Theor. 2. If $(t) = (s)\ (s')$, *then is* $A_{(t)}\ \phi = A_{(s)}\ A_{(s')} \cdot \phi = A_{(s')} \cdot A_{(s)}\ \phi$.

Note.—This result shows that the product of two alternate processes is an alternate process, and that a process $(A_{(t)}$ may be expended in terms of a given minor process $(\,A_{(s)}\,)$.

E. g., $A \cdot p\, q\, r = \frac{1}{3}\,(p\, A\, q\, r - q\, A\, p\, r + r\, A\, p\, q)$, $A \cdot p\, q\, r\, s = \frac{1}{6}\,(A\, p\, q \cdot A\, r\, s + A\, r\, s \cdot A\, p\, q - A\, p\, r \cdot A\, q\, s - A\, q\, s \cdot A\, p\, r + A\, p\, s \cdot A\, q\, r + A\, q\, r \cdot A\, p\, s)$, *etc.*

These are place expansions. Variable expansions give different results,

$$e \cdot g\,.,\ A \cdot p\, q\, r = \tfrac{1}{3}\,\tilde{A}\,(p\,\overset{\frown}{q}\ \overset{\frown}{r} - \overset{\frown}{q}\,p\ \overset{\frown}{r} + \overset{\frown}{q}\ \overset{\frown}{r}\,p)$$

$$= \tfrac{1}{3}\,(p\, A\, q\, r - \tilde{A}\,\overset{\frown}{q}\,p\ \overset{\frown}{r} + A\, q\, r \cdot p).$$ See art. 16.

Cor. 1. $A_{(t)} \cdot \phi = A_{(s')}\, \phi$ (*or* $e_{(s)} \cdot A_{(s')}\, \phi$, *when ϕ is alternate (or symmetric) as to (s) for the arrangemints (s').*

Note.—If (s) be a group this condition means practically for all the arrangements of (t).

Cor. 2. $A_{(t)} \cdot \phi = A_{(s)} \phi$ *(or* $e_{(s')} \cdot \phi$*) when* ϕ *is alternate (or symmetric) as to* (s').

Theor. 3. If (s) *be a group, then* $\cdot A_{(s)} \phi$ *is an alternate function of the group* (s) *for all arrangements of the variables.*

Note.—$A_{(s)} \cdot \phi$ is an alternate function of the group (s) only for those arrangements $s, \ldots$ that satisfy $s\,(s) = (s)\,s$. These include the group (s).

Theor. 4. If (s) *be a group, and* (s') *be any assemblage contained in* (s)*, then,*

$$A_{(s)}\ \phi = A_{(s)} \cdot A_{(s')}\ \phi = A_{(s)}\ A_{(s')} \cdot \phi\ .\ .$$

15. These are the principal theorems of the subject. We note some important special cases where the processes are those that pertain to all the substitutions of given numbers (variables or places).

16. Let A' affect m' given numbers, let A'' affect m'' other given numbers, and so on. Then $A'\ A'' \ldots$ is a process whose factors are commutative and whose substitutions form a group (s), consisting of substitutions that permute each set of variables (or the variables in each set of places) among themselves. One complementary assemblage (s'), such that $(s)\ (s')$ forms the complete group of $\underline{|n}$ substitutions then consists of the substitutions that leave each set of variables (or the variables in each set of places) in their original order among themselves. Any element $s'_{r'}$ of this assemblage may be replaced by any product $s_r\ s'_{r'}$ without charging the assemblage as a complement of (s).

We then have from *th. 2.*

Theor. 2'.

$$A\ \phi = A_{(s')} \cdot A'\ A'' \ldots \phi = \frac{\underline{|m'}\ \underline{|m''} \ldots}{\underline{|n}}\ \Sigma \pm s'_{r'} \cdot A'\ A'' \ldots \phi.$$

In this expansion of $A\ \phi$ in terms of minor $A's$, all terms may be made positive by replacing every negative $s'_{r'}$ by its product by a transposition of (s).

(a). $A\ \phi = A_{(s'}\ \phi$ *(or 0) when* ϕ *is alternate (or symmetric) as to* (s) *for all arrangements of the variables.*

Note.—In particular, *if* ϕ *be symmetric as to certain variables (or places) for all arrangements of the variables, then* $A\ \phi = 0$.

(b). $A\ \phi = A'\ A'' \ldots \phi$ *(or* $e_{(s')} \cdot A'\ A'' \ldots \phi$*) when* ϕ *is alternate (or symmetric) as to* (s').

IV. LINEAR ALTERNATES.

17. A function ϕp is said to be *linear* when $\phi\ (x\,p + y\,q) = x\,\phi\,p + y\,\phi\,q$, where x, y are ordinary numbers (scalars).

18. A function $\phi\ (p_1, p_2, \ldots p_m)$ is a *linear alternate of* m^{th} *order*, when it is linear as to each of its variables. and the interchange of any two variables changes its sign.

Theor. 5. A linear alternate vanishes when one variable is zero, or two variables are equal. It is unaltered by adding to any variable any sum of scalar multiples of the remaining variables. It vanishes when two or more of its variables are linearly dependent —in particular, when the order of the alternate is greater than the order of the algebra.

19. It is easily seen that in an algebra of n'^{th} order the general linear alternate of m'^{th} order is a sum of algebraic multiples of $\underline{n} \; |\underline{m} \;\; |\underline{n-m}$ independent scalar alternates of m'^{th} order.

20. If $\phi\,(p_1, p_2, \ldots pm)$ be a linear function of m'^{th} order, then by *th 3* and note, $\cdot A\,\phi$ and $A\,\cdot\,\phi$ are linear alternates of that order. Also we have more constants than we need (n^m) in order to make either of these the most general linear alternate of m'^{th} order; in fact we have more than enough constants to make also $\cdot\,C\,\phi$ or $C\,\cdot\,\phi$ the most general linear symmetric of m'^{th} order.

21. In the use of $A_{(s)}$ it is not only well to note that it is a linear symbol, but also that it is commutative with any constant linear symbol, ψ, of one variable (such as S, V, K, in quaternions). In applying A, however, to a function ϕ we can not reduce the value of ϕ by reason of any special values of the variables i, e, if for special values of the variables we have $\phi = \phi'$, we do not therefore have $A\,\phi = \phi'$.

22. In any algebra of n'^{th} order, we may take the units $i_1, i_2, \ldots i_n$ as the numbers of n independent directions of unit length (not necessary rectangular). Also, any number $p = x_1\, i_1 + x_2\, i_2 + \ldots + x_n\, i_n$ where $x_1, x_2, \ldots x_n$, are ordinary numbers) may be taken as the number of a line whose components, according to the parallelogram law of addition, are $x_1\, i_1,\; x_2, i_2, \ldots x_n\, i_n$. Taking a fixed origin O, any point P has a definite co-ordinate p, the number of the line $O\,P$. Any number of independent lines have two orders of arrangement such that the interchange of two lines changes the order of arrangement. A change of order in the argument lines of an alternate therefore changes its sign.

23. Consider an m-space bounded by the tangential paths of m independent differentials $d_1\,p,\; d_2\,p, \ldots d_m\,p$. This space may be taken so small as to be approximately an m-parallelogram whose r^{th} pair of opposite faces intersect the lines of $d_r\,p$ and contain the remaining lines through the points of these faces. By $(r - 1)$ interchanges the "r'^{th}" order $d_r\,p,\; d_1\,p, \ldots d_{r-1}\,p,\; d_{r+1}\,p, \ldots d_m\,p$ becomes the "1^{st}" order $d_1\,p, \ldots d_m\,p$. These interchanges may be made so as to leave $d_r\,p$ first. At the initial "r^{th}" face $d_r\,p$ is inward, and we have r interchanges from the r'^{th} order in the differentials exclusive of $d_r\,p$ to bring the r'^{th} order to the first order, say $d'_1\,p,\; d'_r\,p,\; d'_m\,p$, wher $d'_1\,p = -\,d_r\,p$ is *outward.*

24. If $\phi(p, d_1 p, d_2 p, \ldots d_{r-1} p, d_{r+1} p, \ldots d_m p) = \phi_r$, be any function of p, that is linear in the differentials, then if d_r denote differentiation corresponding to $d_r p$, while A affects the subscripts of the differential symbols that follow it, we have for integration through the m space,

$$(-1)^{r-1} \int^m d_r \cdot A \phi_r = \int^{m-1} A \phi (p, d'_2 p, \ldots d'_m p)$$

over the r^{th} pair of faces, where $d'_1 p = \pm d_r p$ is *outward* at each face. Thus summing for every pair of faces and noting that, by *th 2'*, $\Sigma (-1)^{r-1} d_r A \phi_r = m A \cdot d_1 \phi(p, d_2 p, d_3 p, \ldots d_m p)$, we have the following theorem connecting integration through any m-space with integration over the (m-1) boundary of that space:

Theor. 7.
$$m \int^m A \cdot d_1 \phi (p, d_2 p, d_3 p, \ldots d_m p)$$
$$= \int^{m-1} A \phi (p, d'_2 p, d'_3 p, \ldots d'_m p).$$

25. The elements $d_1 p, \ldots d_m p$ are in the same order of arrangement throughout the integration; and at the boundary $d'_1 p, \ldots d'_m p$ are in the same order, with $d'_1 p$ outward.

Any space may be divided into these small finite spaces by the differential lines and the contributions to the boundary integral made by intermediate faces cancel each other, except where the value of ϕ is different on two sides of the same face at the same point of it. In this case such intermediate boundary must be retained in computing the boundary integral.

V. ALTERNATE PRODUCTS.

26. Let $\phi(p_1, p_2, \ldots p_n) = \phi_1 p_1 \cdot \phi_2 p_2 \, \phi_n p_n$.

We then have:

$$n \, A \cdot \phi = \begin{vmatrix} \phi_1 p_1, & \phi_2 p_1, & \ldots & \phi_n p_1 \\ \phi_1 p_2 & \phi_2, p_2, & \ldots & \phi_n p_2 \\ \ldots & \ldots & \ldots & \ldots \\ \phi_1 p_n & \phi_2 p_n & \ldots & \phi_n p_n \end{vmatrix}$$

27. This determinant is multiplied out by ordinary rules, except that since the factors may not be commutative, or even associative, each product must appear in the order and association given by ϕ. The expansions of *Theor. 2'* are then expansions of this determinant in terms of its minors either by rows or columns, according as we employ place or variable substitutions.

28. When two factors of the product ϕ are commutative, for all arrangements of the variables, such factors are also commutative in $A \phi$. The interchange of the corresponding functional symbols alone has, therefore, the same

effect in changing the sign of $A\,\varphi$ as the interchange of the variables alone. Hence when all the factors are commutative, the A may operate either on the variables or on the functional symbols, and since $A\,\varphi$ is linear in the latter, it has the properties of linear alternates with respect to the functional symbols. If the functional symbols be linear, the alternate $A\,\varphi$ is also linear with respect to the variables.

VI. QUATERNIONS.

29. We consider linear alternate products whose functional symbols are *1*, S, V, K. The symbol S gives a factor that is commutative with any other factor, so that any other symbol in the same product with S may be reduced by $+ n\,S$, where n is a scalar.

30. By substituting $1 = S + V$, $K = S - V$ and expanding, our linear alternate product of any order is found to depend on two in which the symbols are either all V or one S and the rest V. Two S symbols give an alternate product that is identically zero (*Theor. 2, note*). It appears that: the two of second order are vectors; the two of third order are a scalar and a vector; one of the fourth order is zero, the other is a scalar. Any linear alternate of fifth or higher order is identically zero.

31. In the geometrical interpretation in which *1*, i, j, k are the numbers of four mutually perpendicular unit lines in four-fold space, the condition of perpendicularity of p, q is $S\,.p\,K\,q = o = S\,.\,K\,p\,.\,q$, *i e.*, $p\,K\,q = -\,q\,K\,p$, $K\,p\,.\,q = -\,K\,q\,.\,p$. Thus in any alternate product whose functional symbols are alternately *1*, K, and whose variables occur in sets, such that any two of different sets are perpendicular, we have

$$A\,\phi = A'\,A'' \ldots \varphi,$$

where $A'\,A''$ are alternate symbols that affect the different sets of variables [*th 2′* (*b*), *art. 16.*] In particular, if all the variables are mutually perpendicular, then $A' = 1$, $A'' = 1$, and $A\,\phi = \phi$.

32. The alternates of second order are:

(a). $A\,.\,Vp\,.\,Vq = V\,.\,Vp\,.\,Vq = L\,i + jM + N\,k.$

(b). $2\,A\,.\,S\,p\,.\,V\,q\,. = 2\,A\,.\,S\,p\,.\,q = A\,i + B\,j + C\,k.$

A, B, C, L, M, N are the six independent scalar linear alternates of second order, and are the coefficients of $\phi\,(1, i)$, $\phi\,(1, j)$, $\phi\,(1, k)$, $\phi\,(j, k)$, $\phi\,(k, i)$, $\phi\,(i, j)$, in the expansion of any linear alternate $\varphi\,(p, q)$.

33. We have further:

(a). $A.pq = A.V.pq = A.Vp.Vq = V.Vp\,Vq = A.Kp.Kq.$

(b). $A.p\,Kq = V.p\,Kq = -2\,A.Sp.q - A.pq.$

(c). $A.Kp.q = V.Kp.q = 2\,A.Sp.q - A.pq.$

Note.—These and similar formulas are useful in computing alternates of higher order. Thus a factor pq of a product may be replaced by $A.\,pg$ [*th 4*] or any of its equivalent values in (*a*) with or without the partial ***A***.

34. Resolve q into $q' + q''$ respectively parallel and perpendicular to *p*. Then $A.p\,Kq = A.p\,Kq'' = p.Kq''$ [*th 6, art* 31_1]. Its tensor is therefore *base* $\times$ *altitude* of parallelogram on *q*, *p*, as sides. We call $A.p\,K\,q$ the *vector* area of the parallelogram (*q*, *p*). It gives plane, direction and tensor, by the plane, direction of turn, and tensor of the vector. Observe that $A.pq = V.Vp\,Vq$ is perpendicular to the three-space $(1, Vp, Vq) = (1, p, q)$.

35. The alternates of third order are:

(a). $A.Vp.Vq.Vr = A.\tilde{A}.V\hat{p}.Vq.V\hat{r} = A.S.Vp.Vq\,Vr =$ $S\,Vp.Vq.Vr.$ We call this scalar $-a$.

(b). $3\,A.Sp.qr = 3\,A.Sp.Vqr = bi + cj + dk.$

The four independent scalar alternates of third order are *a*, *b*, *c*, *d*, respectively the coefficients of $\phi\,(i, j, k)$, $\phi\,(1, j, k)$, $\phi\,(1, k, i)$ $\phi\,(1, i, j)$ in the expansion of any linear alternate $\phi\,(p, q, r)$.

36. We have further:

(a). $A.pqr = A.Vp.qr + A.Sp.qr$

(b). $S.A.pqr = S.Vp.Vq.Vr = S.p\,Aqr = S\,A.p\,A\,qr =$ $\frac{1}{3}S(p\,Aqr + q\,Arp + r\,Apq)$ *etc.*

(c). $V.A.pqr = A.S.p.qr = -A.p.Sq.r$ *etc.*, $=$ $\frac{1}{3}V.(p.Aqr + q\,Arp + r\,Apq)$ *etc.*

(d). $A.p.Kq.r = -S.Apqr = 3.V.Apqr$

(e). $A.Kp.q.Kr = -KA.p.Kq.r = SA.pqr - 3V.Apqr$ $= S.pAqr - 3A.Sp.Aqr.$

Note.—This alternate is Shaw's $A.pqr$, and his formulas hold in the present notation with this value of his $A.pqr$. In the present notation a function that is used as a variable must be enclosed in brackets. Thus $A\,[S\,p]\,q = 0$, where the *S* follows the p, but $A.Sp.q$ is not zero. Similarly, Shaw's value of $A.pq.Arst$ becomes $A.Kp.q.K[A.Kr.S.Kt] = 6\tilde{A}.\hat{r}.Sp\hat{s}.Sq\hat{t}.$

37. Resolve r into $r' + r''$ respectively parallel and perpendicular to the plane of *p*, *q*, and then $A.p.Kq.r = (A.p.Kq).r''$, whose tensor is *base* $\times$ *altitude* of the parallelopiped on *p*, *q*, *r* as edges. We call this the quaternion volume of parallelopiped. It will be shown that this is a line perpendicular to the edges

of the parallelopiped in the relative direction of 1 to i, j, k. We have $A \,.\, p \,.\, Kq \,.\, 1 = -3\, A\, p\, q$. Also $A \,.\, Kp \,.\, q \,.\, Kr$ is the quaternion volume of the parallelopiped $(Kp, Kq, Kr.)$

38. The alternates of fourth order are:

(a). $A \,.\, Vp \,.\, Vq \,.\, Vr \,.\, Vs \,. = 0$, since it is its own conjugate and is in form the vector $A \,.\, Vp \,.\, S \,.\, Vq \,.\, Vr \,.\, Vs$.

(b). $4\, A \,.\, Sp \,.\, Vq\, Vr\, Vs = 4\, A \,.\, Sp \,.\, S \,.\, Vq \,.\, Vr \,.\, Vs = -D$, a scalar. D is the coefficient of $\phi\,(1, i, j, k)$ in any linear alternate $\phi\,(p, q, r, s)$. All our alternates of fourth order are scalars, zero when they can be shown formally as vectors.

39. We have further:

(a). $0 = A \,.\, p\, q\, r\, s = A \,.\, Sp \,.\, V \,.\, q\, r\, s = A \,.\, Vp\, S \,.\, q\, r\, s$, etc.

(b.) $S \,.\, p \,.\, A \,.\, Kq \,.\, r\, Ks = 4\, A \,.\, Sp \,.\, S \,.\, q\, A \,.\, r\, s$
$= -4\, A \,.\, Vp \,.\, V \,.\, q\, A\, r\, s = 4\, A \,.\, Sp \,.\, Vp\, Vq \,.\, Vs$, etc.,
$= A \,.\, S \,.\, p \,.\, Kq \,.\, r \,.\, Ks = A \,.\, p \,.\, Kq \,.\, r \,.\, Ks$, etc.

Note.—The first equation of (b) follows from 36 e, thus: $A \,.\, Kq \,.\, r \,.\, Ks = S \,.\, q\, A\, r\, s - (Sq \,.\, A\, r\, s - Sr \,.\, A \,.\, q\, s + Ss \,.\, A \,.\, q\, r)$, and operating by $S \,.\, p$ we find (b).

Note.—From (b), $S \,.\, s\, A \,.\, Kp \,.\, q\, Kr = -S \,.\, s\, K\, A\, p \,.\, Kq \,.\, r$ is an alternate of fourth order; it therefore vanishes when $s = p, q$, or r, — in other words $A\, p \,.\, Kq \,.\, r$ is perpendicular to the lines p, q, r. To find the order in space make $p, q, r = i, j, k$, whence $A \,.\, p \,.\, Kq \,.\, r = i \,.\, Kj \,.\, k = 1$.

(c). $S \,.\, Kp\, A \,.\, q \,.\, Kr \,.\, s = -S \,.\, p\, A \,.\, Kq \,.\, r\, Ks = D = A \,.\, Kp \,.\, q\, Kr \,.\, s$, etc.

40. Resolve p into $p' + p''$ respectively in and perpendicular to the space q, r, s, thus:

$$A \,.\, Kp \,.\, q \,.\, Kr \,.\, s = Kp'' \,.\, A\, q\, Kr\, s,$$

whose tensor is *altitude* $\times$ *base* of the four parallelogram on p, q, r, s as sides. This is the scalar content of the four-parallelogram, positive when in the order $1, i, j, k$ since, substituting these values in the alternates, the result is $K1 \,.\, i \,.\, Kj \,.\, k = 1$.

41. We have identically $A \,.\, Kp \,.\, q \,.\, Kr \,.\, s \,.\, t = 0$.

Let $p' = A \,.\, q \,.\, Kr \,.\, s$, $q' = -A \,.\, p \,.\, Kr \,.\, s$,
$r' = A \,.\, p \,.\, Kq \,.\, s$, $s' = -A \,.\, p \,.\, Kq \,.\, r$

Then $A \,.\, Kp \,.\, q \,.\, Kr \,.\, s = Sp'\, Kp = Sq'\, Kq$, etc.,

and our expanded identity is,

(a.) $t\, Sp'\, Kp = p\, S \,.\, t\, Kp' + q\, S \,.\, t\, Kq' + r\, S \,.\, t\, Kr' + s \,.\, St\, Ks'$.

42. If $\phi\, s$ be a linear function, we have

(a.) $4\, A \,.\, p \,.\, Kq \,.\, r \,.\, \phi s = c \,.\, Sp'\, Kp$, where $c = 4\, A \,.\, 1 \,.\, Ki \,.\, j \,.\, \phi k$
$= -[\phi 1 + i\, \phi\, i + j\, \phi\, j + k\, \phi\, k]$.

We have $c = -t$ when $\phi s = S t K s$, and (*a*) becomes,

(*b*.) $t S p' K p = p' S t K p + q' S t K q + r' S t K r + s' S t K s$.

43. If $\psi(p, q)$, $\phi(r, s)$ be linear functions, we have $6 . A . \psi(p, q) . \phi(r, s) = c S p' K p$ where $c = A \psi(1, i) . A \phi(j, k) + A \psi(j, k) . A \phi(1, i)$ + two similar terms found by advancing i, j, k.

If $\psi(p, q) = \psi_1 (p K q)$, then $A \psi(1, i) = A \psi j k = - \psi_1 i$, *etc.*

" $= \psi_1 (K p q)$, then $A \psi(1, i) = - A \psi(j, k) = \psi_1 i$, *etc.*

" $= \psi_1 (p q)$, then $A \psi(1, i) = 0 \; A \psi(j k) = \psi_1 i$, *etc.*

" $= 2 \psi_1 (S p . q)$ then $A \psi_1 i = \psi_1 i$, $A \psi(1 k) = 0$, *etc.*

We have thus the identities,

(*a*.) $A . \psi(p K q) \phi(K r s) = 0$.

(*b*.) $A . \psi(p q) \phi(r s) = 0$.

(*c*.) $A . \psi(S p . q) \phi(S r . s) = 0$.

(*d*.) $6 . A . p q . S(r K r_1) S(s K s_1) = A_1 S r_1 . s_1 . S p' K p$.

In fact these methods may be employed to multiply formulas indefinitely. The above are interesting as giving the general relations between the six vector alternates of the same form that may be derived from the quaternions p, q, r, s.

44. We note the following geometrical interpretations: (p_1, q_1, *etc. not affected by A*).

(*a*.) *$2 A . p S . q K q_1$ is a line in the plane (p, q) that is perpendicular to q_1; viz., it is $A p K q$. projection of q_1 on the plane (p, q).*

That it is a line perpendicular to q_1 in the plane (p, q) is seen by its form and the fact that the operator $S . K q_1$ gives an alternate of a symmetric product which is zero by *th 2'*.

Note.—We have, for the complete proof:

$$\widehat{A} . \widehat{p} . K\widehat{q} . \widehat{q}_1 = \tfrac{1}{3} A (p . K q . q_1 - p . K q_1 . q + q_1 . K p . q)$$

$$2 A . p S . q K q_1 = A (p . K . q_1 . q + p . K q q_1) = A (q K q_1 . p + q_1 K q . p) = \tfrac{1}{3} A (2 p . K q . q_1 + p . K q_1 . q - q_1 . K p . q),$$

so that $\widehat{A} . \widehat{p} . K\widehat{q} . \widehat{q}_1 . + 2 A . p S . q K q_1 = A p K q . q_1$. In this result resolve q_1 into $q_1'' + q_1'''$ respectively parallel and perpendicular to the plane (p, q) and it becomes (since $\widehat{A} . \widehat{p} . K\widehat{q} . \widehat{q}_1 = A p K q . q_1'''$),

$$2 A . p . S . q K q_1 = A . p K q . q_1'' \quad Q . E . D.$$

45. Operating on the last result by $S . K p_1$, and remembering, since the planes (p, q), (p_1, q_1''') are perpendicular, that $S . A p K q . A_1 p_1 K q_1'' = o$, we find,

(a). $2 A . S(p K p_1) S(q K q_1) = - S . A p K q . A_1 p_1 K q_1$

= product of areas times cosine of angle between the planes of the parallelograms (p, q), (p_1, q_1). If we drop the subscripts after expansion, we have the squared tensor of the area of (p, q) *viz.*, $T^2 A p K q$.

46. Similarly we have,

(a). $6\,A\,.\,p\,.\,S\,(q\,K\,q_1)\,S\,(r\,K\,r_1)$ = *line in space* (p, q, r) *perpendicular to plane* (q_1, r_1).

This line is therefore $-A_1 \,.\, q_1 \,.\, Kr_1 \,.\, [\,A\,.\,p\,.\,Kq\,.\,r\,]_1$, the constant factor being determined by putting $p, q, r = i, j, k, q_1, r_1 = j, k$. This beeomes, to the factor $S\,r\,K\,r_1$, the line of *44* (a) when r_1 is perpendicular to the plane (p, q)

(b). $6\,A\,.\,S\,(\,p\,K p_1\,)\,S\,(\,q\,K q_1\,)\,S\,(\,r\,K r_1\,)$

$= S\,.\,A\,.\,p\,.\,K q\,.\,r\,K\,.\,A_1 \,.\, p_1\,.\,K q_1\,.\,r_1$

= product of volumes times cosine of angle between the spaces of the parallelopipeds (p, q, r), (p_1, q_1, r_1)

(c). $24\,A\,.\,p\,S\,(q\;K\,q_1\,)\,S\;(\,r\,K r_1)\,S\,(s\,K\,s_1)$ = *line perpendicular* to $(p_1, q_1, r_1) = A_1\,p_1\,.\;K q_1\,.\,r_1\,.\,S p'\,K p$.

This becomes, to the factor $S\,(s\,K s_1)$, the line (a) when $s_1 \perp (p, q, r)$.

(d). $24\,A\,.\,S\,(p\,K p_1)\,S\,(q\,K q_1)\,S\,(r\,K r_1),\,S\,(s\,K s_1)$

$= S\,p'\,K\,p\,.\,S\,p'_1\,K\,p_1$ = product of scalar contents of (p, q, r, s), $(\,p_1, q_1, r_1, s_1)$.

47. We have given sufficient illustrations of the value of alternate processes. The symmetric processes are capable of similar development although we have scarcely touched upon them.

A New Form of Galvanometer. By J. Henry Lendi.

The galvanometer which I am about to describe is a result of the difficulties experienced in attempting to make use of several very sensitive galvanometers in the physical laboratory of the Rose Polytechnic Institute. These difficulties are due to local changes in the earth's magnetic field, arising from moving locomotives, electric motors and street cars in the neighborhood of the laboratory. It will be seen that the existing conditions are anything but favorable to the use of a very sensitive galvanometer depending on the earth's field for the directive force.

In the past year or two several attempts have been made to overcome this difficulty by making a galvanometer of the D'Arsonval type; that is, one in which the directive force is independent of the earth's field. This galvanometer differed only from the ordinary D'Arsonval instrument in that the field was excited by an auxiliary battery instead of a permanent magnet. By this means we were able to secure a very intense controlling field, and thereby, thought we should be able to make a galvanometer more sensitive than the ordinary form of D'Arsonval, and at the same time, make use of it in places where there was a liability to local changes in the earth's field.

But in this we were disappointed, for the reason that it was found impossible to make a deflecting coil free from magnetic impurities in both the insulation of the wire and the wire itself.

This magnetic property of the deflecting coil, it is easily seen, introduced a moment opposite to that which tended to produce a deflection of the coil, and therefore greatly reduced the sensibility of the instrument.

This last difficulty would be entirely eliminated if the controlling field were uniform within the limits and in the direction of the motion of the deflecting coil.

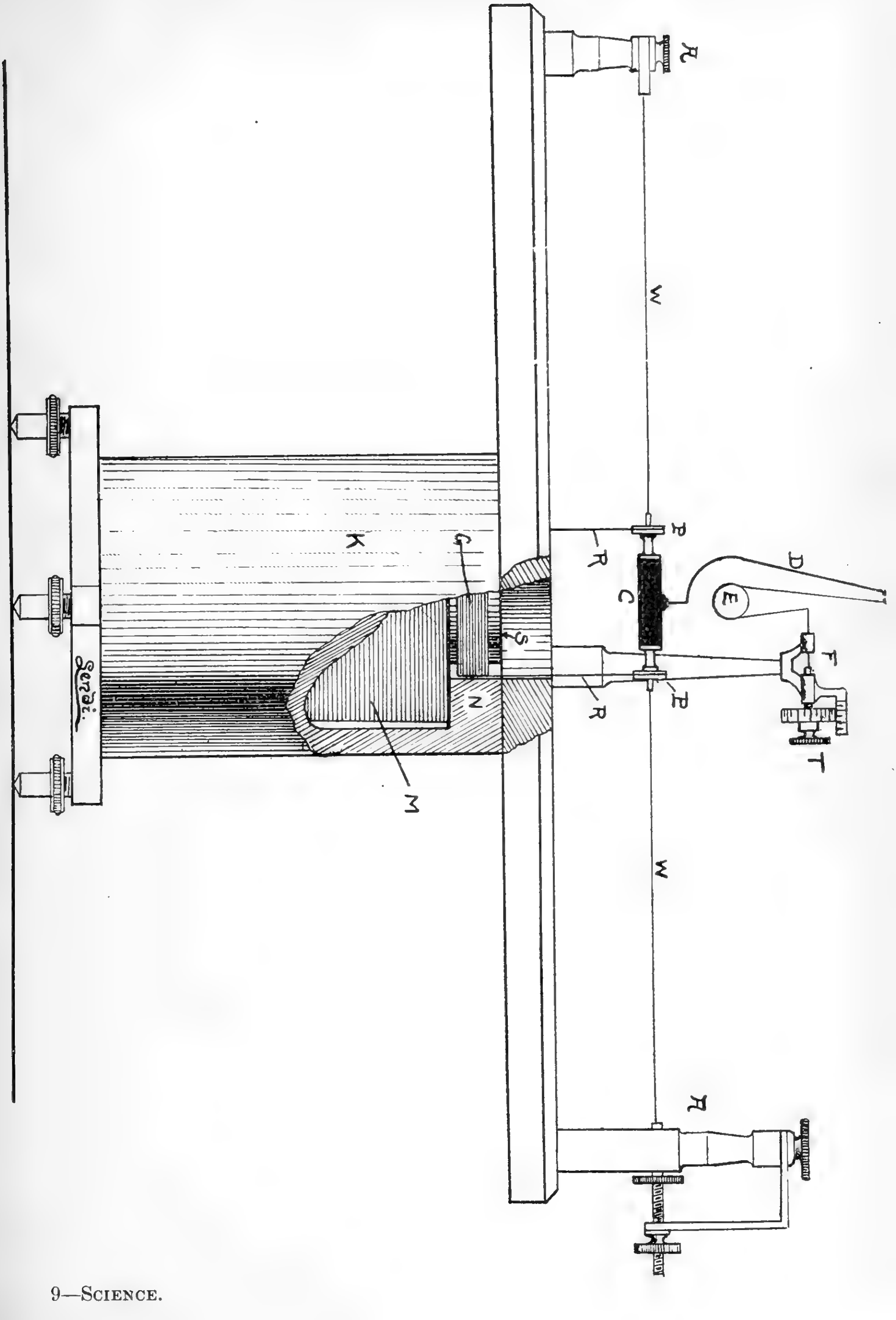
This has, I believe, been accomplished in the instrument I will now describe:

The field magnet is an ironclad electro-magnet of cylindrical form (Fig. 1), the enveloping shell (K) being simply a continuation of the core of the electro-magnet M, the only opening for the magnetic field being an annular slot ⅛" wide, 1⅝" outside diameter and of depth ½". In this slot the deflecting coil (G) is suspended by means of its two terminals (R, R). This form of field magnet will give us a uniform field in the direction of the slot, provided the two cylinders, forming the slot, have their axes parallel, (not necessarily coinciding).

Still another provision was made to guard against the non-uniformity of the field by multiplying the motion between the deflecting coil and the mirror so that a very small displacement of the coil, and consequently insensible change of field in which it hangs, would produce a readable deflection of the mirror.

This multiplication is accomplished by the peculiar suspending mechanism.

Between the two pillars (A, A) there are suspended two light brass pulleys (P, P) by means of the piano wires (W, W) (diameter .01"). These and the wires are insulated from each other by the piece (C), the faces of the pulleys are directly over the field-gap, and wrapped around them are the two terminals (R, R) of the deflecting coil (G), so that an electric circuit can be established between the pillars (A, A) by way of the deflecting coil.


A
W
P
R
C
D
E
F
T
K
G
S
N
M

Again, to the insulating piece (C) there is attached an arm (D) which supports one of the fibers of the bifilarly suspended mirror (E), the other fiber being attached to a fixed pillar (F), which has an adjustment to change the distance between the ends of the fibers. To explain the action of this mechanism, suppose the field magnet (M) to be excited, and thereby producing a very intense magnetic field in the field gap, and that a small current be flowing in the deflection coil freely suspended in this field gap. The result will be an upward or downward motion of the deflection coil, according to the relative directions of the currents in the two coils.

This motion will be communicated by means of the terminals to the pulleys (P, P), which will be rotated about their axis, the piano wire, carrying the arm (D) with them.

It will be seen that if the ratio of the radius of the pulleys to the arm (D) be 1-r, then will the upper extremity of (D) describe an arc whose length is r d, where d is the distance that the coil moves up or down.

Again, suppose the horizontal distance between the upper ends of the bifilar suspension to be s, then will the mirror (E), which, of course, hangs in the plane of the two fibers, make the angle $\text{Tan}^{-1} rd : s$ with its initial position. And therefore for a given value of rd. the deflection of the mirror will approach a maximum as s decreases.

We are thus able to increase the sensibility of the instrument in a very convenient manner, and what is more, we can change it a given amount at will by simply changing the distance s by means of the graduated screw (T).

The instrument has been completed but a short time, and therefore we have not been able to give it a fair test, but the experiments that have been made are sufficient to indicate that, with a few changes in the mechanical details, our object has been attained.

Note on Some Experiments to Determine the Ratio Between the Elastic Limit in Tension and in Flexure for Soft Steel. By W. K. Hatt.

The fact that the material at the top and bottom of a beam of ductile material will show an elastic limit in flexure higher than its elastic limit in tension has been noted by experimenters, by Baoshinger and M. Considere, for instance. For steel bars the elastic limit in flexure was $\frac{1}{3}$ to $\frac{3}{4}$ larger than in tension, and the increase is a function of the shape of cross-section and ductility of material. The increase may be explained by considering that when a beam is bent to the elastic limit of the outside fibres, connection between these fibres and those just below will prevent the free contraction or expansion of the outside fibres, and thus the beam has its elastic strength increased. In case of harder steels and materials such as cast iron or wood, no such increase may be expected. Experiments are being carried on by the writer to determine as completely as possible the increase of the elastic limit as a function of the shape of the cross section. Up to the present a series of ⊤ beams have been tested, and a series of flat plates. The tests in flexure are compared with tests in tension on material cut from the flexure specimens. The plates were partly $6\frac{1}{2}'' \times 1''$ with span of 28″ and partly $7\frac{1}{2}'' \times 1\frac{1}{2}''$ in section with a span of 40″. The increase in the elastic limit for the plates was 55 per cent. in the first case and 27 per cent. in the second case.

A specimen $3'' \times 4''$ in section tested with a span of 57″ showed an elasti limit of 42,000 lbs. □″. A tension test was not made of this material, but the yield point reported by the mill is 37,950 lbs. □″. Mr. Gus Henning has shown that the elastic limit of rolled material is some 4,000 lbs. □″ less than the yield point from the billet, and if the 37,950 lbs. □″ is thus reduced, the 42,000-lbs. □″ elastic limit in flexure will represent an increase of 27 per cent.

When the height increases in comparison with the breadth, the excess strength in flexure disappears, and for the ⊤ beams tested the elastic limit in flexure was slightly less than that of a tension specimen cut from the web.

It is to be noticed also that, in the case of flat plates, there is not free elastic expansion in the side direction during flexure; consequently the modulus of elasticity should be increased. The tests on seven plates show an average increase of 3.6 per cent. in Young's Modulus.

Note on Compressive Strength of Wrought Iron. By W. K. Hatt.

While the tensile strength of wrought iron or steel is a definite quantity, the compressive strength is not so well defined. In the case of wrought iron the compressive strength is quoted by different authors in values from 40,000 to 90,000 pounds per square inch for a state of stress consisting of compression in one direction only. The strength of any specimen is a function not only of its physical properties but of its shape, and the maximum resistance to compression may be anywhere from the elastic limit to the plastic limit, depending on the shape of the specimen tested. It is not customary to test iron and steel in compression, since the results of a tension test give an index of the capacity of the material to resist compression; and, while definite standards exist for the shape of tension specimens, no such widely accepted standards exist for tests in compression. Before defining such a standard we must know the relation between the size and shape of specimens of different grades and their strength. Experiments to determine their relation for wrought iron have been undertaken at Purdue University by the writer, in conjunction with Messrs. Fletemeyer and Alling, and the results are now offered to the Academy.

There were tested 140 square-ended cylindrical specimens, ranging in length from 1 to 10 inches, an area from $\frac{1}{4}$ □″ to 1 □″, covering a ratio of $\frac{Z}{K}$ from 5 to 60. The yield point in compression remained practically independent of the shape of the specimen, and the maximum resistance of the specimen was practically the yield point when the ratio $\frac{Z}{K}$ exceeded 38 (10 diameters). For stouter specimens, whose $\frac{Z}{K}$ was less than 38, the maximum load exceeds the elastic limit by an increasing amount, the excess for a given value of $\frac{Z}{K}$ being the same for different grades of iron, and different area of specimen.

The material was plastic at 77,000 lbs. to □″ with a compression of $\frac{1}{4}$.

The writer would recommend that the term compressive strength should mean either the elastic limit or the limit of plasticity, both of which are definite points.

It does not seem that it is necessary to specify any standard shape of specimen for compression.

Camphoric Acid. By W. A. Noyes.

[Abstract.]

The work done with Mr. E. B. Harris[1] indicates that cis-campholytic acid may possibly be the neighboring △′ tetra hydroxylyllic acid,

$$C_6H_7 \begin{cases} CH_3 & 1. \\ CO_2H & 2. \\ CH_3 & 3. \end{cases}$$

The paper gave an account of work which has been done in the endeavor to prepare this acid. The acid has not yet been obtained, and the difficulties met with have been unusual, but work on the subject is still in progress.

1. Amer. Chem. Jour., *18*, 694, 1896.

CERTAIN COMBUSTION PRODUCTS OF NATURAL GAS. BY P. N. EVANS.

The specimen of material shown was deposited in the course of about three months in a galvanized iron pipe over a natural gas burner in LaFayette, the total quantity being about 500 grams. When first formed the material was waxy in character and accumulated at the lower end of the pipe, which was about four feet in height, but on standing for some months in a closed bottle it became hard and brittle.

Its strong, disagreeable, fishy odor made it seem worth examining, since it was quite unexpected considering the circumstances of formation, resembling trimethylamine, which gives the peculiar odor to herring brine.

As might be expected, the usual tests showed the presence of zinc and iron in the ferrous condition. The material is for the most part soluble in water, the slight insoluble residue having the appearance of oxide of iron.

Barium chloride showed the presence of considerable quantities of sulphate, and on warming with concentrated sulphuric acid the odor of sulphur dioxide was very evident, the evolved gas readily darkening paper moistened with mercurous nitrate, but not darkening lead acetate, showing the presence of sulphites, but not sulphides; the aqueous extract also instantly decolorized a solution of iodine and of iodine and starch. That the sulphur dioxide was not derived by reduction from the sulphuric acid used was shown by the same reactions when hydrochloric acid was substituted.

None of these constituents—iron, zinc, sulphuric and sulphurous acids—were unexpected; neither did they account for the odor. The presence of nitrogen, however, was a surprise, considering that its only source was the free nitrogen of the air and that of the natural gas, which is supposed to contain only very small quantities of the element and in the free state. On warming the substance with a solution of potassium or sodium hydroxide the odor of ammonia was very evident, accompanied by the original fishy smell not noticed when warmed with acid.

To remove all doubt of the formation of ammonia and to learn whether it was accompanied by any considerable quantity of any amine, about 15 grams of the material were distilled with sodium hydroxide and the steam passed into dilute hydrochloric acid. The boiling was continued about 30 minutes, and then the distillate was evaporated to dryness. The residue in the distilling flask retained its fishy odor unimpaired, while the distillate had a very disagreeable odor resembling decaying cabbage. The residue obtained from the distillate was considerable in quantity and gave about 1.5 grams of a yellow platinum compound, which showed on ignition a percentage of 43.52 and 43.55 of platinum in two determinations. The platinum in ammonium chloroplatinate amounts to 43.92 per cent.

These experiments showed, then, about .5 per cent. of nitrogen as ammonia in the deposit—the main point of this communication.

Attempts to show the presence of primary amines by the isocyanide reaction failed, and nothing but the odor seemed to indicate the presence of amines of any kind. A deposit formed in an iron (not galvanized) pipe under similar conditions had little or no odor.

Direct Nitration of the Paraffins. R. A. Worstall.

[Am. Chem. Journal, March, '98; Vol. 20, No. 3.]

Evolution of Free Nitrogen in Bacterial Fermentations. A Preliminary Paper on the Composition of the Gas Evolved in Bacterial Fermentations. By Severance Burrage and A. Hugh Bryan.

During the study of certain species of bacteria in the bacteriological laboratory at Purdue last year, Miss Clara Cunningham found one that produced an enormous amount of gas in fermentation tubes. In fact, the evolution of gas was so rapid and profuse as to attract immediate attention as something extraordinary. The bacillus responsible for this had been separated from sugar beet. It was thought to be of sufficient interest to have the gas analyzed, which was done. The gas was found to be made up of CO_2, H, O and a residual gas which was presumed to be nitrogen. But the occurrence of free nitrogen in this way and in this comparatively large proportion is rare and unusual, and it raised the question whether this could really be nitrogen. No positive test had been made. Every other possible gas had been shown to be present or absent, and nitrogen and argon were all the possibilities remaining. This seemed to be sufficient proof for the chemist, but the bacteriologist wanted a positive proof for nitrogen, which was made, and the nitrogen was found.

In looking up the literature on the subject very little was learned. Nitrogen had been found in a few cases, but no positive tests given. And in some of these cases, on account of the small amount of the nitrogen present, it was thought possible that it might have come from air getting in during the analysis. In several of our analyses the large percentage of nitrogen found would have excluded this possibility. In one case, in our laboratory, the fermentation took place in a fermentation solution which had been made up in the usual way except that no peptone was used. Curiously enough, the percentage of nitrogen in this instance was larger than we found in any other.

A paragraph from an article "On a Pure Cultivation of a Bacillus fermenting Bran Infusions," by J. T. Wood and W. H. Wilcox, B. Sc., will show in a general way how unusual this occurrence of nitrogen is: "A remarkable fact in this fermentation is the evolution of free nitrogen, which seems to be rare, except in the case of putrefactive organisms. As in the vast number of fermentative decompositions due to bacteria, almost the only gases found are carbonic anhydride (CO_2), hydrogen, H_2S and marsh gas."*

In our laboratory this year Miss Lillian Snyder found that a species of bacillus associated with the pear blight, produced a considerable quantity of gas. The analysis of this again showed nitrogen.

The question was raised as to whether the occurrence of nitrogen in these gaseous products of fermentation is really as rare as had been thought. An extensive series of experiments bearing on this subject are in progress, the results of which we hope will to some degree settle this point. So far our results with the same germs and in the same solutions do not give the same proportions of gases. Whether this is a normal variation or due to some causes unknown to us, we cannot say.

The following table shows the results of analyses:

*Journal of the Society of Chemical Industry, June 30, 1897, p. 512.

BACILLUS AND FERMENTATION FLUID.*	CO_2	O	CO	CH_4	H	N
Y.† Smith's Fluid, +2% Sucrose	67	.5	none	none	20.6	11.9
Y. Same as above	61.8	.69	none	none	27.5	10.01
Y. Smith's Fluid, +2% Glucose	38.7	3.6	none	none	36.5	21.2
Y. Smith's Fluid, *no peptone*, +2% Sucrose	37.6	7.2	none	none	21.6	33.4
Y. Smith's Fluid, +5% Sucrose, +3% $CaCl_2$	44.2	1.9	none	none	33.6	10.2
Y. Smith's Fluid, + wort + .7% Acid	53.2	.9	none	none	31.7	14.
Y. Smith's Fluid	45	.83	none	none	26.3	26.8
Y. Smith's Fluid	58.5	none	none	....	31.7	9.8
Y. Smith's Fluid	43.2	none	none	....	40.7	16.2
Y. Smith's Fluid, +2% beet juice	72.7	1.02	none	....	19.7	6.4
X††. Smith's Fluid	50	.2	none	....	32	18

The method of systematic analysis in Hempel's "Gas Analysis" was followed. The gas was transferred from the fermentation tube to a beaker inverted over water and from this to the measuring pipette. Five minutes was allowed for the absorption of the gases and another five minutes before the readings were made. Analyses were conducted where the temperature remained practically constant. The gas was passed into the solutions until no further diminution of volume was noticed.

Carbon dioxide was absorbed by a solution of potassium hydroxide, oxygen by phosphorus and carbon monoxide by an ammoniacal solution of cuprous chloride. Hydrogen was estimated in two ways: (1) By absorption by palladium and (2) by explosion with oxygen. When the latter method was used the gas, after explosion, was passed into potassium hydroxide to make sure of the presence or absence of marsh gas in the

* Fermentation fluid is the common one known as "Smith's" 10 gr. peptone, 5 gr. sodium chloride, 1000 c. c. of water. The additions to this are marked in table.

† Y. Bacillus separated from sugar beet by Miss Clara Cunningham.

†† X. Bacillus separated from pear tree tissue by Miss Lillian Snyder.

original sample of gas. Pure oxygen was used in the explosion, and the excess after it could be absorbed and a residue, if any, measured. In all cases there was a residue of from one to five cubic centimeters, hardly enough for proof of the presence of nitrogen.

In order to prove the presence of nitrogen in the residue, a large fermentation tube was procured and a culture made in this, using the necessary precautions. Smith's fermentation fluid, +1% of glucose, was used. The gases, CO_2, CO, H and O, were absorbed as described before. The residue, amounting to some 20 c. c., was kept in a pipette over water; 10 c. c. of this residue was transferred to a eudiometer provided with platinum electrodes and mixed with 22 c. c. of oxygen prepared from the electrolysis of water. This mixture was sparked. In the course of three hours the volume showed some signs of diminution, and after six hours the volume had been reduced to less than half. The current was turned off and the gas allowed to stand for 24 hours, with no practical change in results.

The contraction in volume of the gas when sparked with oxygen showed the presence of nitrogen in the formation of an oxide of nitrogen which was soluble in water.

Micro-Organisms in Flour. By Carleton G. Ferris.

Flours have been studied from the chemical standpoint with considerable care, but comparatively little has been done as regards investigation from the bacteriological standpoint. Although the chemical side of the question has been considered the most important, as it undoubtedly is, there are certain changes occurring in dough made from chemically pure flour which cannot be attributed to the chemical side of the question. For example, bread made from a flour which chemically contained a proper quantity of gluten, etc., may be spoiled. The point might be raised by some that the bad bread was not the result of using a certain flour, but that the micro-organisms present were found in the water used and in the surrounding air, or possibly from an impure yeast. Experiment has proven, however, that bad bread can be obtained even when sterilized, distilled water and pure yeast are used. As the growth of bacteria does not commence in the dough until nearly all fermentation has ceased, it is reasonable to assume that the changes in the dough and in the bread must arise from some agency present in the flours themselves and independent of the chemical side of the question. Again, in salt-rising bread, where the sponge contains nothing but a chemically pure flour and water, an active fermentation takes place which must be due to the presence of organisms in the flour. Bearing these points in mind, the writer made a series of investigations to determine the micro-organisms found in the flours sold on the local market. A careful canvass of the market was made and samples of the flours sold secured, together with data concerning each. In securing these samples every precaution was used to prevent contamination and to preserve similar conditions throughout. The flours examined include, first, the leading patent flours, most of which are Minnesota products; second, medium-grade flours; third, low-grade flours, commonly called "seconds" by bakers. In these tests the effort was made to determine the condition of each flour under as nearly similar conditions as possible. Each experiment was repeated a sufficient number of times to secure accuracy and overcome abnormal conditions. The ordinary culture media were used, with the addition of blood serum and flour and starch paste. Plate cultures were made, using agar, wort gelatine and broth gelatine. Owing to the fact that many forms liquefy the broth gelatine plates, the number of colonies produced could not be determined, as the plate soon became a mass of mixed forms. Owing to the acidity of the wort gelatine, some forms of bacteria would not grow in it; others liquefied the gelatine, giving the same objection as was applied to the broth gelatine, but to a less degree. Again, moulds grew so rapidly in the wort gelatine that they sometimes crowded the bacteria out. Agar, on account of its nonliquefying properties and comparatively unfavorable condition for the growth of moulds, gave the best results. In occulating for plate cultures, on an average of .0022 grammes of flour were used in each case, hence the comparative number of organisms in each flour could be determined. The names of the flours used are withheld for obvious reasons. The names of the various forms of bacteria found were not always obtainable, as no descriptions could be found in manuals. Of the twelve flours sold on the local market, seventeen distinct species of bacteria were found, one yeast and three moulds—Mucor mucedo, Aspergillus glaucus and Penicillium glaucum. These flours differed greatly as to the number of species obtained from each. Some contained but one form, while others contained as many as seven. Some contained little or no moulds, while others abounded in them. No corroded starch grains were found, showing the flours to be in good condition. The number of bacteria found per gram in the samples by counting the colonies produced on agar plates afford the means of some rather interesting comparisons. For example, Nos. 1, 4, 6, 9 and 11, high-grade patent flours, gave the following number of organisms per gram:

	Bacteria.	*Moulds.*
No. 1	4,090	2,272
No. 4	4,545	909
No. 6	2,727	000
No. 9	4,545	4,090
No. 11	6,363	000

Nos. 3, 7 and 12, medium grade products, gave the following number per gram.

	Bacteria.	*Moulds.*
No. 3	14,545	1,363
No. 7	15,909	2,727
No. 12	18,136	909

Note the increase of organisms produced using the common flours. Using Nos. 8 and 10, low-grade flours:

	Bacteria.	*Moulds.*
No. 8	222,727	000
No. 10	254,545	909

The above figures show beyond a doubt that the high-grade patent flours are much freer from bacteria than the medium and common-grade products. The process seems to affect the number of bacteria in flours. For example: No. 10, manufactured under a poor process, contains more bacteria than Nos. 8, 12 and 3 flours, manufactured under very careful processes.

The number of moulds found in these flours does not vary to the appreciable extent that the bacteria do. Grade seems to be no guide here. Among the 17 different species of bacteria there is one which was found in three of the flours which is a peculiar form, and although its properties seem to be very distinctive, yet no description could be found to answer it. The colonies are hard, dry, and pure white in color, and grow upward from the agar, forming a solid, round and slightly wrinkled mass, which cannot be torn apart by the needle. When the surface is scraped with a needle, the white covering is removed, revealing a brown substratum. This form grows rapidly in agar, wort gelatine, blood serum, starch and flour pastes. The form liquefies wort gelatine slowly, and hard, white lumps float on the surface. This bacterium is a facultative anaerobic bacillus, very short and possessing no movement. Its size is $1 \times 1\frac{2}{3}\ \mu$. Old cultures give a distinct odor of old hay. The cultures of starch and flour pastes containing this form were tested with Fehling's solution to determine the diastasic action, with the result that both the starch and flour pastes showed a very marked action of the changing of starch to sugar, the action in the flour paste being more marked. Eighty-five per cent. of the 17 species grew well in blood serum, the form described above being the most luxuriant grower. It is a curious fact that bacillus subtilis, a form appearing in large numbers on grain, does not appear in the flour. There is not sufficient heat produced in the roller process to kill the bacillus, hence its elimination cannot be traced to that. It has been suggested that possibly the form lived on the husk or bran and clung to it and was thus eliminated. This is only a supposition, however. About 40 per cent. of the different species produced a marked diastasic action in flour and starch pastes,

Briant, Walsh, and Waldo, English chemists, made investigations on this subject, and the conclusions arrived at by them are as follows: The lower the grade of flour, the greater the number of organisms present. That under similar conditions, sourness is far more likely to occur in bread made from low-grade flours.

The writer's investigations of flours confirm the above results.

DESCRIPTION OF FORMS.

Flour No. 1 contains 3 forms: a (1), B (1) (c).

a (1) Is a facultative anaerobic, non-liquefying micrococcus. Grows well in agar but not so well in wort gelatine. Has a grayish color grown on agar. Colonies oily, and smooth. Size is $1\frac{1}{2}\ \mu$. Arranged in twos and fours, and possesses no movement. Does not grow on blood serum.

B (1) Is a facultative anaerobic, non-liquefying bacillus. Grows well in agar, but poorly in wort gelatine. The colonies are grayish white in color, dull, dry and floury, with convoluted edges. Possesses a slow, waddling movement. Size, $3 - 9 \times 1\ \mu$.

c Is a facultative anaerobic, non-liquefying bacillus. Grows very well in agar, but does not grow at all in wort gelatine. The colonies are yellow with a greenish tinge, growing in concentric layers. The colonies are smooth and oily. This form does not grow in blood serum. Has a waddling movement straight ahead. Size, $6 \times 1\,\mu$.

Flour No. 2 contains 3 forms: a (2) a (3) (c′).

a (2) Is a facultative anaerobic, liquefying bacillus. Grows slightly more in agar than in wort gelatine. Full description has been given in the body of this article.

a (3) Is a facultative anaerobic, liquefying bacillus. Grows well in agar and wort gelatine. Liquifies gelatine and produces a marked white film over the surface. The colonies are oily, smooth and regular, of a grayish color. This form is $3 - 9\,\mu \times 1\,\mu$, and possesses no movement.

c (1) Facultative anaerobic, non-liquefying coccus form, groups of two or more. Grows well in agar, but does not grow at all in wort gelatine. The colonies are smooth and oily, with smooth edges. Pink in color. Is $1\frac{1}{2} - 1\,\mu$ diameter. Possesses no movement.

Flour No. 3 contains 4 forms: a (1) a (2) c (1), same as No. 2 (c′) and d (1).

a (1) Aerobic, liquefying, bacillus, growing singly and in filaments. This form grows very well in both wort gelatine and agar. The colonies are tough and slimy, with smooth edges. Yellow in color. Size is $3 \times \frac{3}{4}\,\mu$, and possesses no movement.

a (2) Facultative anaerobic, liquefying bacillus. Grows well in agar; not so well in wort gelatine. The colonies are grayish yellow in color, oily and slimy, with irregular edges. This bacillus is $3 \times \frac{3}{4}\,\mu$, and possesses no movement.

c (1) Pink variety same as No. 2 c (1).

d (1) Facultative anaerobic, non-liquefying bacillus. Grows well in agar, and very slightly in wort gelatine. The colonies are yellow, tree-like in form, with firm edges, with the center slimy and oily. Form is $3 \times 4\,\mu$ in size and has a slow, waddling movement.

No. 4 flour contains 6 forms and one yeast: a (2) e (1) b (2) a (1) c (1) d (1) and yeast f (1).

a (2) Facultative anaerobic, non-liquefying bacillus. This form grows well in agar, but does not grow at all in wort gelatine. The colonies are grayish yellow, oily, slimy, and have smooth edges. Size, $3 - 4\frac{1}{2} \times \frac{3}{4}\,\mu$. Has a burrowing movement.

T (1) Turns out to be a red yeast twice as long as broad, differing from all red yeasts previously noted. Has granular contents vacuoles, large and vary from 1 — 5 in number. Gross appearnce, very dull, firm, pink on agar. Also grows well in gelatine. Some cells show spore like bodies at each end. Size, $6 \times 3\,\mu$.

e (1) White variety. Same as No. 2 a (2).

a (1) Same as No. 1 a (1).

B (2) Facultative anaerobic, liquefying bacillus. Grows well in agar and wort gelatine. The colonies are yellow, iridescent smooth, oily, with smooth edges. Size is $3 \times \frac{3}{4} \mu$, and possesses slight jerky movement.

c (1) Facultative anaerobic, liquefying bacillus. Grows well in agar and wort gelatine. The colonies are yellow, smooth, oily with smooth edges. Size, $1\frac{1}{2} \times \frac{3}{4} \mu$. Has no movement.

d (1) Facultative anaerobic, liquefying bacillus. Grows well in agar and wort gelatine. Colonies, yellowish white, slimy, oily, irregular edges. Liquefies gelatine entirely, forming a white and firm film over the surface, also a heavy sediment is formed. The gelatine becomes red brown in color, on agar an emerald green color appears near surface of the agar. Size, $2 \times \frac{3}{4} \mu$. Has a movement in circles.

Flour No. 5 contains two forms c (2) B (2).

c (2) Facultative anaerobic, non-liquefying, zoogloea mass. Very luxuriant grower in both agar and wort gelatine. Colonies are smooth and oily, with smooth edges. This form is yellow in color.

B (2) Facultative anaerobic, liquefying bacillus. Good grower in wort gelatine and agar. Colonies are yellow, smooth and slimy, with smooth edges. Produces a little gas. Size, $4\frac{1}{2} \times 1 \mu$. Possesses no movement.

Flour No. 6 contains but one bacterium, same as No. 3 d (1).

Flour No. 7 contains 4 forms: a (1) a (3) b (1) b (3).

The white form a (3) same as No. 2 a (2) also b (1) same as No. 5 b (2).

a (1) Facultative anaerobic, liquefying bacillus. Good grower in wort gelatine and agar. Colonies are dark yellow in color, slimy and oily, with smooth edges. Size, $2\frac{1}{4} \times 1 \mu$. Possesses no movement.

D (3) Facultative anaerobic, liquefying bacillus. Good growths in agar and wort gelatine. Colonies are yellow in color, smooth, oily, with regular edges. Size, $2\frac{1}{2} \times 1 \mu$. Possesses no movement.

Flour No. 8 contains 3 forms:

a (3) Same as No. 2 a (2).

a (2) Same as No. 3 d (1).

a (1) Same as No. 5 B (2).

Flour No. 9 contains 2 forms:

a (1) Same as No. 5 b (2).

a (2) Same as No. 2 a (2).

Flour No. 10 contains one form:

b (2) Same as No. 4 d (1).

Flour No. 11 contains 2 forms.

a (1) Same as No. 1 a (1).

a (2) Same as No. 3 a (1).

Flour No. 12 contains 3 forms.

a (1) Same as No. 7 b (3).

b (1) Same as No. 4 b (2).

c (1) Same as No. 2 a (3).

No.	No. of Forms.	Bac. Per Gram.	Moulds Per Gram.	Grade of Flour.
1	3	4090	2272	High.
2	3	2727	2727	High.
3	4	14545	1363	Medium.
4	6–1 yeast.	4545	909	High.
5	2	9090	909	Medium.
6	1	2727	000	High.
7	4	15909	2727	Medium.
8	3	222727	000	Poor.
9	2	4545	4090	High.
10	1	254545	909	Poor.
11	2	6363	0000	Medium.
12	3	18136	909	Poor.

This work was done under the direction of Miss Katherine E. Golden.

The Number of Micro-Organisms in Air, Water and Milk as Determined by Their Growth Upon Different Media.

By A. W. Bitting.

While conducting a series of experiments to determine the number of bacteria and moulds in milk, some variations in number were found when the tests were made upon different culture media. This led to an experiment to determine the number of micro-organisms present in air, water and milk, using agar agar, glycerine agar, beef gelatine, and wort gelatine. The results of the test were somewhat of a surprise. The agar agar, glycerine agar and beef gelatine were neutral, while the work gelatine was slightly acid, but the degree of acidity not determined. Ten exposures were made with each media, using petri dishes and kept as close together as possible. The conditions were evidently as nearly alike as it is possible to obtain.

The average number of bacteria and moulds which developed is as follows:

	Bacteria.	Moulds.
Agar agar	86	3
Glycerine agar	73	7
Beef gelatine	64	20
Wort gelatine	41	34

Ten tests of water gave the following result:

	Bacteria.	Moulds.
Agar agar	2,370	12
Glycerine agar	2,260	15
Beef gelatine	1,470	60
Wort gelatine	480	88

Ten tests of milk gave the following results:

	Bacteria.	Moulds.
Agar agar	7,967	2
Glycerine agar	11,207	7
Beef gelatine	7,416	12
Wort gelatine	1,700	47

Agar agar shows the highest number of colonies of bacteria, and wort gelatine the highest number of moulds. The inference is that a statement of the number of forms found in anything should be accompanied by a statement of the media used and how prepared.

THE EFFECT OF FORMALIN ON GERMINATING SEEDS. BY M. B. THOMAS.

Having had occasion during the past year to investigate the application of formalin as a germicidal agent, I became greatly interested as to the possibility of its use as a fungicide.

Some very imperfect laboratory experiments suggested the probability of its value in connection with the destruction of the smut of corn, oats and wheat, and accordingly plans were made to carry out a series of experiments with this in view. More careful thought on the subject convinced me that such experiments would prove too expensive unless some accurate data were at hand regarding the effect of formalin, in solutions of varying strength, on the germination of seeds. Accordingly, as a preliminary investigation, I began in connection with Mr. C. E. Crockett, a student in the department, a careful series of such experiments with the seeds of grains and other plants.

All of the details of the experiments were carefully arranged to prevent a possibility of error and a very pure solution of formalin was secured. In all cases parallel experiments were conducted and check tests made with the seeds soaked in pure water.

The work was carried on in the green house, where the soil was kept at a nearly constant temperature. The seedlings usually began to appear above the ground by the fifth day, and were measured daily for two weeks, then weekly until well advanced in their development. Seeds were grown both in pure sand and rich earth to determine the possible effects of soils on the treated specimens, but in all of the experiments no difference was noticed from such varying conditions, as the seeds planted in the sand compared in every respect in their behavior with those grown in rich soil. In all cases the temperature of the solution in which the seeds were soaked was about 19° C.

With the wheat ½ and 2 per cent. solutions were used, and the time of treatment varied from one-half to four hours. The results show that of the seeds soaked in the ½ per cent. solution for one-half hour, 76 per cent. germinated; for one hour, 56 per cent., and for 3½ hours, 36 per cent. While of those treated for one hour in a 2 per cent. solution none germinated.

Wheat seemed to be about the most easily affected by the formalin of any seed, and even the use of a ½ per cent. solution for one-half hour is not safe. A ¼ per cent. solution for about this length of time will prove the most satisfactory.

The results of the experiments showed that the plants of the treated seeds developed as rapidly and perfectly as those of the untreated ones. In a few instances, where retarded germination was evident as a result of this treatment, the plants soon made up this deficiency and at the end of two weeks could not be distinguished from the others. The fact that wheat was one of the easiest affected of any of the grains is no doubt due to the very imperfect protection of its embryo.

With oats, of those soaked in a ½ per cent. solution for one-half hour, 96 per cent. of treated and a less number of untreated germinated, and one, two and three and a half hours, soaking did not materially decrease the relative percentages, while with those treated with a 2 per cent. solution for one hour only 48 per cent. germinated, and none showed life after four hours soaking. It will therefore be seen that oats can endure the treatment much better than wheat.

An interesting condition in the increased percentage in the germination of the treated seeds as compared with the untreated ones in all of the tests can allow of little explanation. The plants of the seeds treated up to four hours were, after a few days, quite a little larger than those of the untreated ones, and this condition remained constant throughout the development of the plant. It seemed that in this case the formalin must have in some way contributed to the development of the plant, notwithstanding the statement of T. Bokorny* that this substance ununited was not beneficial to growth.

It is evident, however, that oats can safely be treated for three hours in a ½ per cent. solution of formalin without danger of injury to the germinating power of the seed.

With rye, 44 per cent. germinated after soaking in a ½ per cent. solution for one hour, with but a slight decrease in the number after four hours treatment. With the 2 per cent. solution none germinated after three and a half hours treatment. It is therefore evident that rye will not endure the treatment as well as wheat.

In the case of corn, after soaking in a ½ per cent. solution for one hour 92 per cent. germinated, equaling the per cent. that developed from the untreated seeds. After two hours in the solution a very slight decrease was noted, and after three and a half hours only 52 per cent. germinated. After the use of a 2 per cent. solution for one hour but 56 per cent. developed. Corn, therefore, seems to endure the treatment fairly well, and the use of a ½ per cent. solution for one hour will not decrease the per cent. of seeds that germinate.

Buckwheat, millet, beans and other seeds were treated with quite satisfactory results, and while no use can probably be made of such a treatment with these seeds, yet their behavior was interesting as illustrating the general effect of formalin on germinating seeds and developing seedlings.

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* Landsw. Jahrb., 21 (1892), pp. 445–446.

After the use of solutions that seemed to be about the maximum strength allowable, germination was often delayed for two or three days as compared with that of the untreated seeds, and in one case with treated oats some did not germinate until the third week.

In the case of all plants studied the use of formalin did not in any way change the character of either the stem, leaves or root in those that germinated, as far as could be observed, except as above stated in certain exceptional cases. No corrosive action was observed, as is found in the case of extended treatment with copper sulphate, that seems to act quite freely on the tip of the radicle.

If, as has been predicted, formic aldehyde in very dilute solutions prove an efficient fungicide, there seems to be no reason why it should not take the place of the well-known copper—sulphate or hot-water treatment for smut of grains.

The great reduction in price, the ease of manipulation and its general all-round efficiency as a germicidal agent will make its use more certain by the agriculturist, especially in place of the hot-water process, where no little inconvenience is experienced in arranging for treatment and in keeping the hot water at a correct temperature.

This paper is intended to be suggestive rather than exhaustive, and the full statistics now on hand will be published at some future time, if the practical field experiments to be conducted in the spring warrant the continuing of the investigation.

Since the work covered by this paper was completed I have been able to find in some cases an indirect reference to the use of formalin in 1: 10,000 for destroying the spores of smut.*

SUMMARY.

The use of formalin for destroying smut spores is very clearly an important proposition.

The small expense of the treatment and the facility of its application commend it for a thorough trial, at least.

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* (1) Low. Ueber einen Bacillus, welcher Ameisensäure und Formaldehyd assimiliren kann. Central. für Bak. und Parasitenkunde. Bd. XII, S. 462.
(2) Comptes Rendues, 1892.
(3) Annales de Micrographie, 1894–95.
(3) Recherch. sur la valeur de la formal. u. s. w. Arch. de pharmacodynamie, 1894, Vol. I.
(4) Bericht id. Gesellschaft für Morphologie und Physiologie. München, 1888.

The use of a 2 per cent. solution is too strong for all grains, even with a short application.

A ½ per cent. solution is about right for oats, and the treatment may be continued for as long as two hours without injury to the seed.

For wheat a treatment with a ¼-per-cent. solution for one-half hour is safe, while a ½ per cent. solution for the same time will not decrease the germinating power of the seeds to any considerable extent.

Corn may be treated for two hours with a ½ per cent. solution without injury.

Rye is injured in a ¼ per cent. solution for one hour.

When germination is slightly retarded by the treatment, the plants soon equal in their development those of the untreated seeds.

A List of the Mycetozoa Collected Near Crawfordsville, Indiana. By E. W. Olive.

The accompanying list comprises forty-three Myxomycetes, thirty-two of which are not reported in Dr. Underwood's "List of Cryptogams of Indiana," in the Proc. Ind. Acad. Sci., 1893, p. 30.

Duplicates have been deposited in the herbarium of Prof. M. B. Thomas, Wabash College, Crawfordsville, and in the Cryptogamic Herbarium of Harvard University.

The determinations have been made according to the descriptions in the Monograph of the Mycetozoa, by A. Lister.

The collections were made mostly in August, 1897, and with few exceptions the species seemed to be comparatively abundant, several gatherings being made of many of them. The majority of the species were found upon decaying stumps and logs, while a few were fruiting upon living leaves and stems, and still others on moss and fallen leaves.

Two instances were noted of a curious growth of the very abundant *Physarum cinereum* Pers. A circle about six feet in diameter was clearly outlined in both cases by the grayish sporangia fruiting upon the living leaves and stems of grass and Plantago. The border of the ring was pretty regular and five or six inches broad. Here and there within the ring were small groups of sporangia, but the most were confined to the outer border. The plasmodium had probably been feeding upon the dead grass stems lying close upon the ground, and, as it grew in size, crawled outward from the center, when a dry and hot day caused simultaneous fruiting, thus resulting in a regular ring of sporangia. The formation is thus quite similar to the circles formed by the "fairy-ring mushroom," or *Marasmius.*

MYXOMYCETES.

Arcyria albida Pers.
Arcyria flava Pers.
Arcyria punicea Pers.
Badhamia hyalina, Berk.
Ceratiomyxa mucida Schroet, var. *genuina* List.
Ceratiomyxa mucida Schroet, var. *flexuosa* List.
Chondrioderma michelii Rost.
Chondrioderma reticulatum Rost.
Chondrioderma testatum Rost.
Comatricha typhoides Rost.
Craterium leucocephalum Ditm.
Cribraria aurantiaca Schrad.
Cribraria intricata Schrad. var. *dictyoides* List.
Diachæa elegans Fries.
Diachæa splendens Peck.
Dictydium umbilicatum Schrad. (a form.)
Didymium clavus Rost.
Didymium effusum Link.
Enteridium (*olivaceum?*) Ehreub. with *free* spores.
Fuligo septica Gruelin.
Hemitrichia clavata Rost.
Hemitrichia rubiformis Lister.
Hemitrichia serpula Rost.
Lycogala miniatum Pers.
Oligonema nitens Rost.
Perichæna populina Fries.
Physarella mirabilis Peck.
Physarum bivalve Pers.
Physarum cinereum Pers.
Physarum contextum, Pers.
Physarum leucopus Link.
Physarum nutans Pers.
Physarum (*rubiginosum?*) Fries.

Physarum variabile Rex.
Physarum viride Pers.
Spumaria alba DC.
Stemonitis ferruginea Ehreub.
Stemonitis fusca Roth.
Stemonitis splendens Rost.
Trichia affinis De Bary.
Trichia favoginea Pers.
Trichia persimilis Karst.
Tubulina fragiformis Pers.

ACRASIEAE.

Chondromyces lichenicolus Thaxter.
Myxococcus stipitatus Thaxter.
Myxococcus rubescens Thaxter.

The Germ of Pear Blight. By Lillian Snyder.

It is certainly an established fact that the well-known disease of Pear Blight, which causes such devastation among our pear, apple and quince trees, is caused by bacteria within the growing tissue of the tree. The germ which causes the disease was discovered by T. J. Burrell, and was first described and named by him in 1882.*

The germ I have isolated from the pear tree, and which I think I can say without a doubt causes the disease of the tree, I shall designate by the name used by other writers, and originated by Prof. Burrell; that is, Micrococcus amylovorus. Whether the above germ spoken of is the same as the one handled and studied by Prof. Burrell, and also by J. C. Arthur,† I leave to be gathered from the results of my experiments. Early in March, 1897, I attempted to separate the germ which causes the blight of the tree. Various methods were used, such as cutting pieces of diseased bark of pear, with a sterilized knife, and placing in bouillon; also by inserting a platinum needle between the bark and wood of diseased tissue and streaking upon agar. The latter proved the most success-

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*Eleventh Report of the Illinois Industrial University, p. 42.

†Proceedings of the Philadelphia Academy of Nat. Sciences, 1886, pp. 322–341.

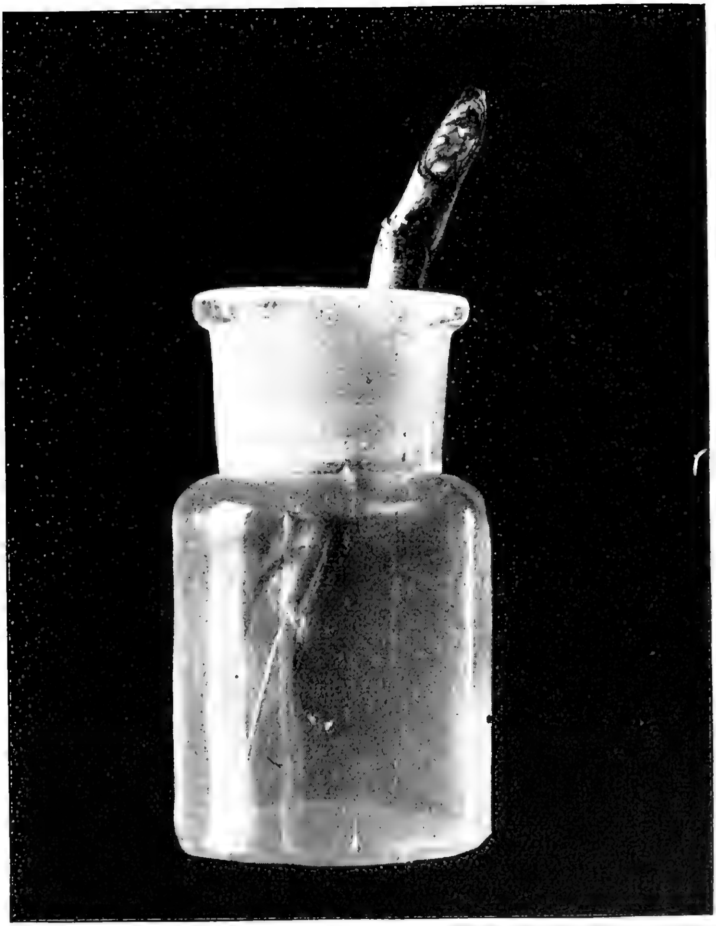

Fig. 1.—Pear twig in water with the germ micrococcus amylovorus growing upon the cut surface.

ful, and by this method a germ was obtained which I carried through a number of experiments and found to be in many respects like the germ described by Dr. Arthur in his History and Biology of Pear Blight. This germ was studied and kept alive until the latter part of May, when the pear was putting forth its new shoots, the young branches being then used for inoculation. Out of about ten inoculations, at different times, not one appeared to have any effect upon the tree. I concluded I was mistaken in the germ, which resulted in a second attempt to isolate the germ from the tree.

By this time the trees were in all their foliage, thus making the disease much more readily detected than previously. The same method was used as above described as successful, and out of six or seven attempts to transfer the germ from the host upon agar, five were successful. This germ thus obtained was then used to inoculate into the young growing shoots of the tree (Bartlett pear), and every inoculation that was made caused blight of the tree. This was during the month of June, the temperature being on an average of 70° F., the atmosphere moist, rainfall 5.16 inches, being 1.34 above normal, thus favorable for the increase in growth. At the end of a week after the blight first began to appear it was not unusual to see the branches blighted 10 or 12 inches from the point of inoculation.

In inoculation only perfectly healthy pear and apple trees were used, the former taking the disease with much more readiness than the latter. The germ was taken from streak cultures upon agar, a sterilized platinum needle being used to transfer the germ to the surface of the young twigs. After the surface had been smeared over with the germ, openings were made through the bark layers at this point, enabling the germ to get well started to grow before it might be washed off by rain.

Leaves do not take the blight when inoculated. Naturally, the germ appears to be confined to the branches, the leaves only dying when their nourishment has been cut off.

GENERAL CHARACTERS OF MICROCOCCUS AMYLOVORUS.

The cells are oval, very little longer than broad, being about .59μ to .89μ wide by .89μ to 1.2μ long. Cells are colorless, very refractive and difficult to stain, resembling spores in their relation to stain. The best results in staining were obtained with carbol fuchsine. When grown upon agar the cells are usually found single, very often in pairs and occasionally in chains of fours. When growing in bouillon or other nutritive media the germ exhibits independent movement, thus differing from the habits of the germ within the host. When sections of the diseased branches are placed under the microscope the bacteria show very little, if any, movement.

This germ appears to be aerobic, and increases in growth with an increase of temperature.

Growth upon agar was most rapid during the months of July and August, the average temperatures for these months being 73.3° F. Later in the season the germ ceased to grow with the same rapidity, although exposed to a high degree of temperature.

Spore formation was not observed, and I am inclined to believe spores are not formed.

CULTURES WITH LIQUID AND SOLID MEDIA.

Cultures with bouillon after 48 hours at 30° C. remained perfectly clear, the growth all settling to the bottom of the tube. Not in any case have I observed zooglœa formed.

In a pure corn-starch solution inoculated with the germ, the germ survived and multiplied, but the starch was not chemically changed. Two cellulose solutions* made from Swedish filter paper were used. In one glucose was used and the other sugar was not added. In these solutions I planted the germ, and at the end of a week no apparent change had taken place in either solution, but the one which did not contain sugar originally was tested, and it was found that cellulose had been changed into glucose.

Various fermentation fluids were used, but this germ does not ferment under any conditions.

The most convenient solid media for the cultivation is agar. Colonies are white, slightly opalescent, when vigorously growing raising like beads from the surface. In a streak culture the outline is slightly feathery. Agar which had not been titrated, but used as made up, slightly acid, was found to give the best results in the growth of the germ.

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*Cellulose solution was made up as follows; Peptone, 10 grams; Salt, 5 grams; Glucose, 20 grams; Pure Cellulose, 20 grams; Water, 1000 C. C.

In a stab culture in nutrient gelatine the growth spreads over the surface and along the line of inoculation, but does not penetrate the gelatine, thus remaining for several weeks without any sign of liquefaction.

Probably the most characteristic result is the growth upon pear twigs. The end twigs to a length of two or three inches were cut from the tree. These were placed in water, the upper cut surface covered with the growing germ, and the vessels containing the twigs then placed under a bell jar for 24 hours. At the end of this time about two out of every four of the twigs had a beautiful growth over the cut surface. This growth was in the form of globules, as many as three or four globules being on one twig. These bead-like colonies, being white and raised from the surface, were perfectly apparent to the unaided eye. (See Fig. 1.) This growth increases, turning yellow when old, until entirely destroyed by moulds.

Another very important characteristic of Micrococcus amylovorus is the manner of growth within the growing pear fruit. A half-sized Bartlett pear upon the tree was inoculated in about the same manner as the branches had been. The pear ceased to grow and soon began to shrivel. At the end of two weeks the pear was removed from the tree, and upon examination the whole interior was found to be composed of a soft, milky substance, which appeared under the microscope to be made up entirely of bacteria.

Half-ripe pears were taken from the tree, cut in slices, inoculated with the germ, and then placed under a bell jar. Colonies were found in 24 hours, which resembled those already described upon agar.

During the month of October cultures were taken from quinces which has been inoculated with M. amylovorus. This second germ proved to be entirely different from M. amylovorus, but alike in all respects to the germ separated from the tree in March. This germ, which I shall term No. 2, I feel convinced occurs within the tree. But what relation it bears to M. amylovorus, if any, I am not prepared to say.

Germ No. 2 when transferred to pear twigs in water grows very well, but does not survive or grow with the same vigor as M. amylovorus does when placed under the same conditions. The growth of No. 2 is not raised in bead-like colonies, but grows in a continuous mass, over the surface, and instead of being white, is transparent.

Microscopically the two germs are so near alike it is impossible to separate them. They bear about the same relation to stains and the cells are of about the same size. The arrangement of the cells of the two germs differ some, but this is not constant.

CULTURES WITH LIQUID AND SOLID MEDIA.

Cultures with bouillon after 24 hours at 30° C. are very turbid, and a thick pellicle is formed over the surface of the liquid. The germ grows well in a corn-starch solution, but the starch is not broken down. Cellulose solutions made as above stated were inoculated. At the end of two days both had fermented, thus in the one without sugar, sugar had been formed. In this one in which sugar was formed the gas production was very slow.

Germ No. 2 planted in Smith solution causes fermentation and gas forms very rapidly. Mr. A. H. Bryan, a student of Purdue University, who was so kind as to analyze the gas produced by this germ, has given the following results of his analysis:

From germ No. 2, separated from the pear tree in March, 1897:

CO_2	45.0 per cent.
O	.83 per cent.
H	26.3 per cent.
CH_4	0.00 per cent.
	73.13 per cent.
Remainder or N	26.87 per cent.

From germ No. 2, separated from the quince in October, 1897:

CO_2	50 per cent.
O	None.
CO	None.
H. by Palladium	32 per cent.
Total	82 per-cent.
Remainder or N	18 per cent.

It is presumed that the remainder in each case is nitrogen, but just what per cent. is nitrogen is not yet known.

Gelatine was inoculated while liquid, then allowed to solidify. At the end of two days colonies appeared as small white dots beneath the surface of the gelatine. In gelatine thus inoculated with M. amylovorus such colonies were not apparent.

Upon agar the only essential difference in the two germs that might be noted is that germ No. 2 grows much more rapidly than M. amylovorus does when exposed to the same temperature.

This paper has been prepared under the direction of Dr. J. C. Arthur, to whom I am very much indebted for a number of suggestions which have been of great value in my experiments.

WATER POWER FOR BOTANICAL APPARATUS. BY J. C. ARTHUR.

In vegetable physiology a number of kinds of apparatus are required which must be run at an approximately uniform speed. Some of the most important of these pieces are used to influence the direction of growth, and as plant movements dependent upon growth are slow, the apparatus must often be kept in motion continuously from twenty-four to seventy-two hours or more.

The chief reliance where the movement is very moderate, ranging as it does for clinostats between ten to sixty minutes for one revolution, has usually been some form of clock-work, regulated by escapement or fan. For comparatively rapid movement, such as a centrifuge requires, which ranges from fifty to five hundred revolutions per minute, recourse is generally had to water or electric power. Both of these sources prove very unsatisfactory as a rule, for machines doing such light work as the physiologist requires, and especially when they must be run steadily and without interruption both day and night.

Electric power from a commercial plant usually varies greatly, and, moreover, is rarely continuous for the twenty-four hours. If the power is taken from a battery of some form of cells, the difficulty of maintaining a uniform current is almost as great, beside the annoyance of caring for the cells. The potash cells, especially those sold under the name of Edison-Lalande, have given the best satisfaction for this kind of work of any so far tried in the laboratory of Purdue University. But even these are treacherous, and quite uneven.

Water power, if secured, as is customary, by connection with a tap in the laboratory, has some of the disadvantages of electric power in being inconstant. Every tap in the vicinity that is opened or closed varies the pressure, and even the initial pressure can by no means be depended upon.

After many and vain efforts to obtain efficient power for my laboratory the following plan was hit upon, and has proved wholly satisfactory. The method is very simple. It consists in providing a tank with an inlet valve operated by a float. As the water is withdrawn from the tank the float sinks and opens the valve, and the inflowing stream of water brings the water in the tank back to the full height. As the inlet valve permits a much larger stream of water to pass than the outlet valve does, the tank always stands essentially at the same level.

The simplicity of my whole arrangement is one of its particular features. The tank consists of a vinegar barrel. It is set upon a platform in the story above my laboratory, and gives a fall of about fifteen feet. The water supply is taken from the city water that is piped throughout the building. The pipe conducting the water to the laboratory below is a small lead pipe and siphons the water over the top of the barrel. It is almost as easily put in place as rubber tubing, and can readily be changed to reach any part of the laboratory. It is closed at the lower end with a short piece of rubber tubing and a screw pinchcock, with which connection can be made with a water motor or other apparatus. The float and valve in the barrel are such as plumbers usually furnish for dwelling houses.

With this arrangement a practically uniform head of water is available at all times, and although a fall of more than fifteen feet would be desirable, yet it has proven ample to run a centrifuge, using a Crowell water motor.

A larger tank and more extensive plumbing might be used, but the arrangement as I have described it is so easily constructed and inexpensive as to be available in almost any laboratory.

Many more uses of a small constant stream of water will come to mind than those mentioned. For instance, it is almost indispensable in running such an aspirator as is used for aerating seeds in a respirometer or for producing a regular alternating movement by filling a pair of buckets set on a pivot. The cheapness and uniformity of the power are its great merits.

Contributions to the Flora of Indiana, No. V. By Stanley Coulter.

Since the last report to the Academy, two plants worthy of note have been added to the State flora by Prof. Blatchley.

Vitis rupestris Scheele.—On sand ridges in Lake county. The plant had first been called to my attention by Mr. H. C. Cowles, of Chicago University, and was doubtfully referred to *V. cordifolia* Michx. Later Prof. Blatchley sent me fruiting specimens from the same general region which proved that the plant could not be so referred. The specimens were sent to Prof. L. H. Bailey, of Cornell University, who determined them to be *V. rupestris*. This grape is essentially southern in its mass distribution, its recorded range being from Missouri to Texas, Tennessee and the banks of the Potomac near Washington. It is difficult to understand how it could have wandered so far from its original range, although, as Prof. Bailey writes, "botanists have ceased being surprised at anything from that region."

Juniperus nana Willd., (=*J. communis*, L., var. *alpina* Gaud.).—From Lake county. This form has entered our flora from the north, its recorded range being from Maine to Minnesota and northward.

Much work has also been done during the past year in the extension of the range of various species, largely through the labors of Dr. Hessler, Prof. Blatchley and Mr. W. W. Chipman. It is not, however, so much the purpose of this contribution to report upon the work done during the past year as to summarize the data now in the hands of the survey, in the hope that much needed information may be furnished before the final publication of the State Flora.*

After excluding manifestly introduced forms, recorded as "escapes," together with incorrect references due to a scarcity of material, 1,369 species have been passed upon by the State survey and admitted to the State flora. These species are distributed through 534 genera and 124 families. The list is doubtless far from complete, but under the rules of the survey no plant can be admitted unless verified by an herbarium specimen or one that has been passed upon by some recognized authority. For the most part the admitted species are represented by herbarium

*In previous contributions to the State Flora, the nomenclature followed was that of "Gray's Manual," 6th edition. This was done for the purpose of ready correlation of the facts given in the contributions, with the records of observers. In this contribution it is thought best to use the nomenclature of the "List of Pteridophyta and Spermatophyta," prepared by the Botanical Club of N. A.

specimens, although some forms recorded in Dr. J. Schneck's "Flora of the Lower Wabash," determined by Dr. Gray, have been admitted in the absence of verifying specimens. The same is true as regards a few forms contained in the "Alpine Flora of Indiana," by Dr. A. J. Phinney, which were submitted to Dr. John M. Coulter for determination. If unverified forms, which have been reported from various parts of the State, were added, the number of species would reach at least 1,500. In the summarized statement which follows it will be noticed that the reports concerning many of the more widely distributed families are manifestly incorrect. This is notably true in the case of the grasses and sedges, and scarcely less evident in the case of the umbellifers and the crucifers. It is hoped that botanists throughout the State will examine this list carefully and report needed corrections:

No.	Families.	Genera.	Species.
1	Coniferæ	6	9
2	Typhaceæ	1	1
3	Sparganiaceæ	1	1
4	Naiadaceæ	2	8
5	Juncaginaceæ	2	2
6	Alismaceæ	3	4
7	Hydrocharitaceæ	2	2
8	Gramineæ	27	47
9	Cyperaceæ	11	48
10	Araceæ	4	5
11	Lemnaceæ	2	2
12	Xyridaceæ	1	1
13	Eriocaulaceæ	1	1
14	Commelinaceæ	2	4
15	Pontederiaceæ	2	3
16	Juncaceæ	2	6
17	Liliaceæ	20	35
18	Smilaceæ	1	5
19	Amaryllidaceæ	3	3
20	Dioscoreaceæ	1	1
21	Iridaceæ	3	4
22	Orchidaceæ	14	36
23	Saururaceæ	1	1
24	Juglandaceæ	2	9
25	Myricaceæ	1	1
26	Salicaceæ	2	12
27	Betulaceæ	2	10
28	Fagaceæ	3	18
29	Ulmaceæ	2	6
30	Moraceæ	3	3
31	Urticaceæ	4	4
32	Santalaceæ	1	1

No.	Families.	Genera.	Species.
33	Aristolochiaceæ	2	3
34	Polygonaceæ	4	29
35	Chenopodiaceæ	3	9
36	Amaranthaceæ	3	8
37	Phytolaccaceæ	1	1
38	Aizoaceæ	1	1
39	Portulacaceæ	1	1
40	Caryophyllaceæ	10	27
41	Nymphæaceæ	5	7
42	Magnoliaceæ	2	2
43	Anonaceæ	1	1
44	Ranunculaceæ	16	42
45	Berberidaceæ	4	4
46	Menispermaceæ	1	1
47	Lauraceæ	2	2
48	Papaveraceæ	7	9
49	Cruciferæ	17	39
50	Capparidaceæ	2	2
51	Sarraceniaceæ	1	1
52	Droseraceæ	1	2
53	Crassulaceæ	2	5
54	Saxifragaceæ	8	15
55	Hamamelidaceæ	2	2
56	Plastanaceæ	1	1
57	Rosaceæ	18	54
58	Leguminosæ	27	77
59	Geraniaceæ	2	4
60	Oxalidaceæ	1	3
61	Linaceæ	1	4
62	Rutaceæ	2	2
63	Simarubaceæ	1	1
64	Polygalaceæ	1	8
65	Euphorbiaceæ	5	18
66	Limnanthaceæ	1	1
67	Anacardiaceæ	1	6
68	Aquifoliaceæ	2	3
69	Celastraceæ	2	4
70	Staphyleaceæ	1	1
71	Aceraceæ	1	5
72	Hippocastanaceæ	1	2
73	Balsaminaceæ	1	2
74	Rhamnaceæ	2	3
75	Vitaceæ	2	6
76	Tiliaceæ	1	2
77	Malvaceæ	6	11
78	Hypericaceæ	2	15
79	Cistaceæ	3	4
80	Violaceæ	2	17
81	Passifloraceæ	1	1
82	Cactaceæ	1	1
83	Thymelaceæ	1	1
84	Elæagnaceæ	1	1
85	Lythraceæ	5	5

No.	Families.	Genera.	Species.
86	Melastomaceæ	1	1
87	Onagraceæ	8	17
88	Hallorhagidaceæ	3	7
89	Araliaceæ	2	3
90	Umbelliferæ	21	26
91	Cornaceæ	2	9
92	Pyrolaceæ	2	6
93	Monotropaceæ	2	2
94	Ericaceæ	11	18
95	Primulaceæ	9	13
96	Ebenaceæ	1	1
97	Styraceæ	1	1
98	Oleaceæ	2	6
99	Gentianaceæ	5	13
100	Apocynaceæ	2	3
101	Asclepiadaceæ	4	14
102	Convolvulaceæ	2	8
103	Cuscutaceæ	1	5
104	Polemoniaceæ	2	10
105	Hydrophyllaceæ	3	7
106	Boraginaceæ	8	18
107	Verbenaceæ	3	7
108	Labiatæ	24	56
109	Solanaceæ	5	13
110	Scrophulariaceæ	20	42
111	Lentibulariaceæ	1	4
112	Orobanchaceæ	3	3
113	Bignoniaceæ	2	3
114	Pedaliaceæ	1	1
115	Acanthaceæ	2	3
116	Plantaginaceæ	1	9
117	Rubiaceæ	6	18
118	Caprifoliaceæ	6	18
119	Valerianaceæ	2	5
120	Dipsaceaeæ	1	1
121	Cucurbitaceæ	3	3
122	Campanulaceæ	3	12
123	Compositæ	48	189
124	Cichoriaceæ	7	25
	Total	534	1,369

An examination of the table shows that fifteen families are represented by twenty-five or more species, the composites leading with one hundred and eighty-nine. These fifteen families contain 772 species, leaving 597 species to be distributed among the remaining 109 families. Dominant families, such as these, are, of course, of general distribution throughout the State and have naturally been more closely studied than many of the others. It is probable that further study will place the sedges and grasses in the third and fourth places instead of the fifth and sixth, in which they are now found. Twenty-seven families are represented by a single species, so far as reports have come to the survey.

Of the 1,369 species, about one hundred and fifty are hydrophytes, about one hundred xerophytes, the remainder being mesophytes. The hydrophytic area has its center in the lake region in the northern counties and in the marsh lands of the Kankakee River, though in a lesser degree occurring along waterways and in local swamp regions. The true xerophytic flora is for the most part confined to the sand regions near Lake Michigan, although along the roadbeds of the older railways true xerophytes are occasionally found.

The mesophytic flora of the State is being largely modified and the hydrophytic flora is rapidly disappearing or assuming mesophytic adaptations because of the extensive drainage of swamp regions. With the drainage of the Kankakee marshes many forms, now a part of the flora, will disappear. Evident modifications of the flora are also occurring as the result of cultivation of the soil, and the removal of forest areas and undergrowth. The effects of these changes are especially noticeable in the virgin forest areas that still remain. In Marshall county such an area carefully preserved from the time of the entering of the land for settlement, has within the last few years shown a marked and rapid loss of value; the tops and larger branches dying, and in many cases the main trunk also showing signs of decay. It is estimated that within five years the timber has decreased in value at least twenty-five per cent. The apparent modifications of conditions are, clearing of adjacent forest areas leaving the virgin tract isolated, cultivation of the lands up to the borders of the area and an enormous increase in the number and carrying capacity of the tile drains. The timber of the area is "mixed," as is the rule in Indiana forests, but no species seems exempt from the effects of these changed conditions. It is possible that the trees may have approached their normal life and that the changed conditions have merely served to hasten the decay properly chargeable to age. That this inference can scarcely be true, is shown from the fact that in Jackson county and the lower stretches of the Wabash much larger and evidently much older forms of the same species maintain themselves in full vigor. In Hamilton county and in other localities the Beeches have been most seriously affected. This is possibly due to a lowering of the soil water line resulting from tile draining. The root-habit of the Beech would lead us to expect that it would be among the first forms to be affected from this change of the water level in the soil. Such an explanation, however, would not suffice for the Marshall county case, where the deep rooting forms are as seriously affected as the beeches. The part played by the other factors mentioned in the production of this forest decay is yet to be studied. The subject is of such importance that it will be carefully studied before the issuing of the State flora.

The floral regions of the State as indicated by Coulter and Thomson in the "Origin of the Indiana Flora,"* need some modification in the light of a more extended knowledge of the flora of the State. The seven floral districts of Coulter and Thomson were based largely upon geological horizons and altitude, factors which are quite subordinate in the limited area of Indiana in the determination of plant distribution. The effect of altitude must be very slight in an area in which the lowlands are about three hundred feet above sea level and the highlands only from 900-1,300 feet above. The number of plants whose distribution is limited by geological horizons must necessarily be very small in a State so largely affected by the drift and in which the amount of soil derived from the country rock remaining *in situ* is so comparatively insignificant. It is not meant that these factors may not be of importance in other regions or when widespread areas are considered, simply that in Indiana they are not dominant and do not furnish the most natural basis for the division of the State into floral districts. Without doubt, within our area, waterways furnish the dominant factor in determining plant distribution. That this is true can be easily verified by checking the mass distribution of almost any abundant form upon a hydrographical map of the State. This is not the place to discuss in detail the proposed redistricting of the State, but during the coming season outline maps indicating approximately the boundaries of the proposed floral regions will be distributed to the working botanists of the State for suggestion and criticism.

The general movement, especially of our summer and fall blooming plants is toward the northwest. This was of course to have been expected from the direction of the prevailing winds at the time of such dissemination. This movement is quite marked and can be noticed in almost every instance in the case of plants accidentally introduced into the State through the agency of railroads. In the case of the Russian thistle

*Indiana Geological Reports, Vol. XIV., p. 255.

and other recently introduced forms this fact is very apparent. Local conditions may modify this movement somewhat. Thus in the northwestern counties of the State the movement of the plants, especially those of the sand soils is to the south and southeast because of the winds from Lake Michigan. The very slight overlap of the characteristic prairie flora of Illinois into corresponding regions in Indiana is well known, and has its explanation in the above facts. An examination of the flora of the State, and a consideration of the mass distribution of the forms involved shows that a very large proportion of it is from the east and southeast, very little from the west. Marked overlaps occur with the true southern forms in the southwestern counties, and with northern forms in the Lake region, but this is to be expected from the topographical and hydrographical features of the regions.

The weeds of the State have received much attention, and while a full treatment of the subject is reserved for the final report of this division of the survey, a few facts are here given in the hope of securing additional data bearing upon this very important subject.

Salsola kali tragus (L.) Moq., the Russian thistle has not spread to any great degree. As indicated in a former paper,* its appearance in Lake and Noble counties was reason for the belief that its distribution in the State would be limited, a belief happily justified by the facts. Its disappearance from the regions in which it is now found is but a question of time.

Lactuca scariola L., the prickly lettuce, is rapidly spreading throughout the State and is becoming one of our most dangerous forms. It spreads with extreme rapidity and by its rank growth shades out many smaller forms and takes sole possession of large tracts. In a piece of waste land covering about ten acres, I noted, three years ago, perhaps a half dozen plants. Last year the land was entirely taken by the lettuce. None of our weeds demands more vigorous measures for its repression, and its first appearance in any region should be the signal for the beginning of repressive measures.

Solanum rostratum Dunal, widely heralded a few years ago as a dangerous weed, has not spread widely and is practically confined to the regions in which it first found lodgment. It was first reported from Vigo and Sullivan counties having come in from the west, and this position

* *Noteworthy Indiana Phanerogams*, Stanley Coulter, Proceedings Indiana Academy of Science, 1895, p. 192.

rendered the probability of any great spread over the State exceedingly slight. The plant should, however, be carefully watched, although at present not of sufficiently general distribution to take rank among the dangerous weeds of the State.

Erigeron annuus Pers., white top, which had apparently been practically eliminated from the list of weeds of the State, has during the past two years appeared in great abundance throughout the State. In many cases it has entirely taken meadows in which it had been practically unknown for years. Reports of its occurrence came to me from a large number of counties with requests for an explanation of its sudden reappearance. No satisfactory explanation has as yet suggested itself, but as the plant yields readily to careful cultivation it may be considered as annoying rather than dangerous.

Rumex acetosella L., field or sheep sorrel, while not a conspicuous landscape feature is in many respects to be considered the most dangerous weed in the State. It spreads rapidly and because of its early leafing and habit of growth supplants the grass and other desirable forms. It sets root deeply and resists successfully all of the ordinary means of weed eradication. Apparently so long as the smallest portion of the root is left in the ground there is danger ahead. I have records of many cases in which the farmer has given up what seems a hopeless contest and has abandoned his fields.

In the light of to-day, the introduction of new weeds is not to be greatly feared. The persistence of our indigenous forms is, however, quite a different matter. The presence of these noxious weeds is not merely a constant disgrace, but also a constant menace. The passage and enforcement of wisely devised weed laws would prove of incalculable benefit to the State, and it should be the part of botanists to urge the passage of rational and workable laws upon this subject.

Experiments in Germination of Composites. By Stanley Coulter.

[Abstract.]

A report upon one hundred experiments in the germination of composites, confirming positions taken in a paper presented to the Academy last year. These positions were as follows:

1. The achenes of composites show a low germination percentage.

2. The achenes of the earlier and later flowers are as a rule not viable.
3. The seedlings are especially sensitive to heat and temperature changes.
4. The period of the vitality of the achene is rarely more than two years.

Detailed report is reserved until more extended experiments are made.

The Mycorhizæ of Aplectrum. By D. T. MacDougal.

The Tendrils of Entada Scandens. By D. T. MacDougal.

The Ericaceæ of Indiana. By Alida Mabel Cunningham.

In determining the distribution of the Ericaceæ in Indiana there is encountered the same difficulty as in the case of so many other families. A complete and thorough botanical survey of the State would be a task involving untold labor, and, however enthusiastic the collector, the time and expense involved in such an undertaking will necessarily delay for some time the accomplishment of the work. As a result, comparatively few localities in the State have yet been fully reported. But it is a matter of still greater regret that so much of the work done in the past has been a mere waste of energy, the reports left so incomplete, and even the name of the worker, in many cases, is unknown. The last State catalogue* reported twenty species of Ericaceæ and six have since been added by various collectors. These species represent nineteen counties, and eleven have no collector named from any county in the State.

The only species I have been able to find in Tippecanoe County is *Monotropa uniflora* L. In the summer of 1895 I found eight specimens. They were growing in a thick growth of timber, chiefly white oak and black oak, on a heavy-clay soil. The next year the same timber land was visited and they were found there of the most perfect character and in the greatest profusion all over the tract of

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*Of these twenty species, *Oxydendrum arboreum*, D. C., *Kalmia angustifolia* L., *Rhododendron nudiflorum* Torr., and *Pyrola secunda* L. are not found in Monroe County, as recorded in the State catalogue, and are to be excluded from State Flora. This leaves the number of known species twenty-two.

land; while last summer, 1897, but two specimens were discovered, and they very imperfect ones. It is probable that the difference in their occurrence was due to the varied supply of moisture. The summer of 1895 was unusually dry, while in 1896 there was an extremely heavy rainfall a few days prior to the appearance of the plants, and 1897 being again exceptionally free from moisture. However, this species has a greater distribution than has any other one found in the State, being reported from fourteen different counties.

The following list represents the different species reported as found in the State:

Gaylussacia frondosa Torr. and Gray is reported from Clark county only. (B. and T.).

Gaylussacia resinosa Torr. and Gray. Reported from Jefferson county (C. R. B.), Monroe county (W. S. B.), Clark county (B. and T.), Noble county (Van G.), also in counties about Lake Michigan.

Vaccinium is represented by seven species.

Vaccinium stamineum L. is reported from Johnson county (C. R. B.), Clark county (B. and T.), Monroe and Lake counties.

Vaccinium Pennsylvanicum Lam. Monroe and northern tier of counties.

Vaccinium vacillaus Solander. Reported from Lake county.

Vaccinium corymbosum L. is reported from Cass county only, by Mr. Hessler.

Vaccinium corymbosum var. *pallidum* Gray. Reported from Noble county (Van G.) and from Lake county.

Vaccinium oxycoccus L. Only record is in Lake county.

Vaccinium macrocarpon Ait. Reported from Cass county (R. H.), Noble County (Van G.), Jay county (P.).

Arctostaphylos Uva-ursi Spreng. Counties about Lake Michigan.

Epigæa repens L. is reported from Monroe county (W. S. B.), Laporte County (McD.), "Montgomery and Lake counties."

Gaultheria procumbens L. is reported from Cass county (R. H.), Noble county (Van G.). "Counties about Lake Michigan."

Andromeda polifolia L. is a northern form, being reported from Cass county (R. H.), Noble county (Van G.).

Cassandra calyculata Don. is another northern form, and is reported from Cass county (R. H.), Noble county (Van G.), and "counties about Lake Michigan."

Kalmia latifolia L. Reported from Monroe county only.

Chimaphila umbellata Nutt. Reported from the following counties: Noble (Van G.), Jefferson, Monroe and Lake.

Chimaphila maculata Pursh. is reported from Putnam county (McD.), Franklin county (M.), Jefferson and Monroe counties. "Counties about Lake Michigan."

Pyrola chlorantha Swartz is reported from Lake county by E. J. Hill.

Pyrola rotundifolia L. Found in Noble county by Van G.; also reported from Lake county.

Monotropa uniflora L is reported from the following counties: Franklin (M.), Clark (B. and T.), Jay, Delaware, Randolph and Wayne (P.), Putnam (McD.), Monroe (W. S. B.), Jefferson (J. M. C.), Cass (R. H.), Noble (Van G.), Gibson and Posey (S.), Tippecanoe (A. M. C.).

Monotropa hypopitys L. is reported from the following counties: Clark (B. and T.), Noble (Van G.), Vigo and Monroe (W. S. B.), Cass (R. H.), Franklin (M.), Jefferson and Monroe.

In the distribution of the Ericaceæ throughout the State we find the following species confined entirely to the northern part, *i. e.*: *Vaccinium corymbosum* L., *Vaccinium Oxycoccus* L., *Arctostaphylos Uva-ursi*, Spreng., *Andromeda polifera* L., *Cassandra calyculata* Don., and *Pyrola chlorantha* Swartz.

Gaylussacia frondosa Torr. and Gray is found only in Clark county (B. and T.).

The remaining species, with the exception of *Kalmia latifolia* L., are of general distribution.

Indiana's Gentianaceæ. By Alida Mabel Cunningham.

Gray's Manual includes ten genera of Gentianaceæ, seven of which come within the range of Indiana; therefore, we might reasonably expect to find one or more species in nearly every county in the State. Unfortunately a comparatively small portion of the State has, as yet, been thoroughly botanized, and we find reports from only nineteen of the ninety-two counties. As reported the range by counties is from Lake on the north to Clark and Jefferson on the south, and from Jay on the east to Vigo on the west.

The reports show that six genera and fourteen species have been found in Indiana. Of these the genus Gentiana is represented by eight species, leaving the remaining six species to represent five genera.

Of the different species named in the list below but four have come under my own personal observation, and in the reports of some of the others I find wanting much that is required to make them of any great value. For instance, those reported from Marion, Harrison and Washington counties fail to show when or by whom collected. Other counties, however, report the same plants with authority, except in the case of one, *i. e.*, *Gentiana puberula* Michx., which is not reported from any other locality in the State. Many do not show in what portion of their respective counties they were found, the character of the soil, the requirements as to moisture, or whether the plant is rare or abundant.

If we may be permitted to draw a conclusion based upon these reports, we would say the length of the list indicates that the Gentianaceæ are rare in the State; for, although a very small portion of the State has yet been systematically botanized, surely flowers of such exquisite loveliness as are the Gentians would scarcely escape the eye of the most casual observer, and even in those counties where the work has been most thoroughly and systematically done they are not represented by a large number of species. Doubtless the time is past for finding a great number of species of Gentianaceæ in Indiana, for the every appearance of this flower would indicate that it is too delicate a plant to withstand the encroachment of cultivation and would beat a hasty retreat before the march of improvement. Hence the cause for regret that the work done by the early collectors is of so little real value to science; for unquestionably there were then to be found here many forms of plant life that have now forever disappeared from the State. It is to be hoped that all future collectors of plants, of whatsoever description, will see that their collections are properly accredited to them, and further that they make their reports full and complete, that the future student may know something of the distribution of the plant, whether rare or abundant, and whether he may reasonably expect to find it growing in a swamp or a gravel bank, in the valley or on the hilltop.

The following is a list of all the Gentianaceæ of which I have been able to find even a trace in Indiana:

Sabbatia is represented by two species:

Sabbatia brachiata Ell. is reported only from Jefferson county by Dr. J. M. Coulter.

Sabbatia angularis Pursh. is reported from Gibson and Posey counties (S.), Cass county (R. H.), Franklin county (M.), Jefferson county (J. M. C.), Clark county (B. and T.), Lauramie Township, Tippecanoe county, August, 1897. Only a few specimens were found growing in rich, black soil in the edge of timber. (A. M. C.).

Gentiana crinita is reported from Cass county (R. H.), Noble county (W. B. Van G.), Wayne county (P.), Marion county.

Gentiana serrata Gunner is reported from only two counties—Noble (W. B. Van G.), west central portion of Lauramie Township, in the southeast corner of Tippecanoe county along the Little Wea Creek. It was found growing in a marsh adjacent to the creek in 1896. The area over which it was found was, perhaps, an eighth of an acre in extent, and this entire area might be truthfully described as a mass of the bright, rich purple of this magnificent flower. The same place was visited in 1897 and not a single specimen could be discovered (A. M. C.).

Gentiana quinqueflora Lam. is reported from Franklin county (M.), Noble county (W. B. Van G.), Marion county, "Happy Hollow," one-half mile north of West Lafayette, Tippecanoe county. Common in rich, moist places along the foot of the bluffs. September, 1896 (A. M. C.).

Gentiana quinqueflora Lam., var. *occidentalis* Gray, is reported only from the "Knob" region by Dr. Clapp.

Gentiana puberula Michx. Reported from Harrison and Washington counties. No authority.

Gentiana Saponaria L. is reported from Vigo county (W. S. B.).

Gentiana Andrewsii Grieseb. is more generally distributed than any other species, being reported from twelve counties, *i. e.:* Jay, Delaware, Randolph and Wayne in the east; Jefferson, Gibson and Posey in the south; Vigo in the west; Monroe and Franklin in the central, and Noble and Cass in the north.

Gentiana alba Muhl. is reported from Cass county (R. H.), Vigo and Monroe counties (W. S. B.), Noble county (W. B. Van G.), Gibson and Posey counties (S.), "Happy Hollow," one half mile north of West Lafayette, Tippecanoe county. But a single plant was found growing among a thick growth of timber on a gravelly clay soil on top of a bluff. August, 1896 (A. M. C.).

Frasera Carolinensis Walt. ranks next to *Gentiana Andrewsii* Grieseb. in distribution, being reported from nine counties: Cass county (R. H.), Noble county (W. B. Van G.), Jay, Delaware, Randolph and Wayne counties (P.), Gibson and Posey counties (S.), Franklin county (M.).

Bartonia tenella Muhl. is reported from Noble county only, by W. B. Van Gorder.

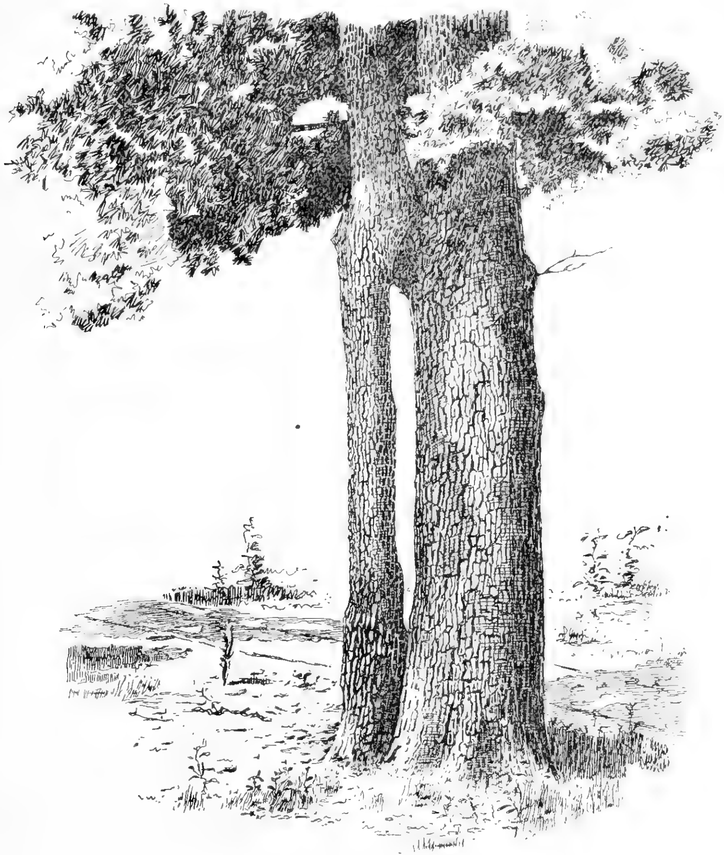
Obolaria Virginica L., as far as our knowledge goes, is confined to the southern and central portions of the State, being reported from Gibson and Posey counties (S.), Clark county (B. and T.), Vigo and Monroe counties (W. S. B.), Jefferson county (C. P. V.).

Menyanthes trifoliata L. seems to be an exclusively northern form, being reported from Lake county (E. J. H.), Noble county (W. S. Van G.), Cass county (R. H.), Kosciusko county (W. W. C.).

Inarching of Oak Trees. By John S. Wright.

On the western border of what is known as Cypress Swamp, or Pond, in the "pocket" of Knox county, and at the side of the wagon road, about one-third of a mile east of the locks at the Wabash Rapids, I observed last September an interesting case of natural grafting of forest trees. The united trees were, judging from the leaves, there being no fruit obtainable, specimens of Swamp, Overcup or Post Oak, *Quercus lyrata* Walt.

The trees stood close together, so close in fact that a careful examination only showed that the trunks were actually separate at the ground. The larger of the trees was about eighteen inches in diameter one foot



above the ground, the smaller about nine inches. As shown in the photograph, the trunks were separate to a height of about eight feet, where they were united by a large protuberance which seemed to have its origin in the larger tree, as it partially enveloped its trunk. A section of this connection would be of an irregular oval shape, the longer dimension in line with the axes of the trunks. This longer diameter would measure about two feet. The union seemed to be of a healthy, woody growth, covered with rough bark.

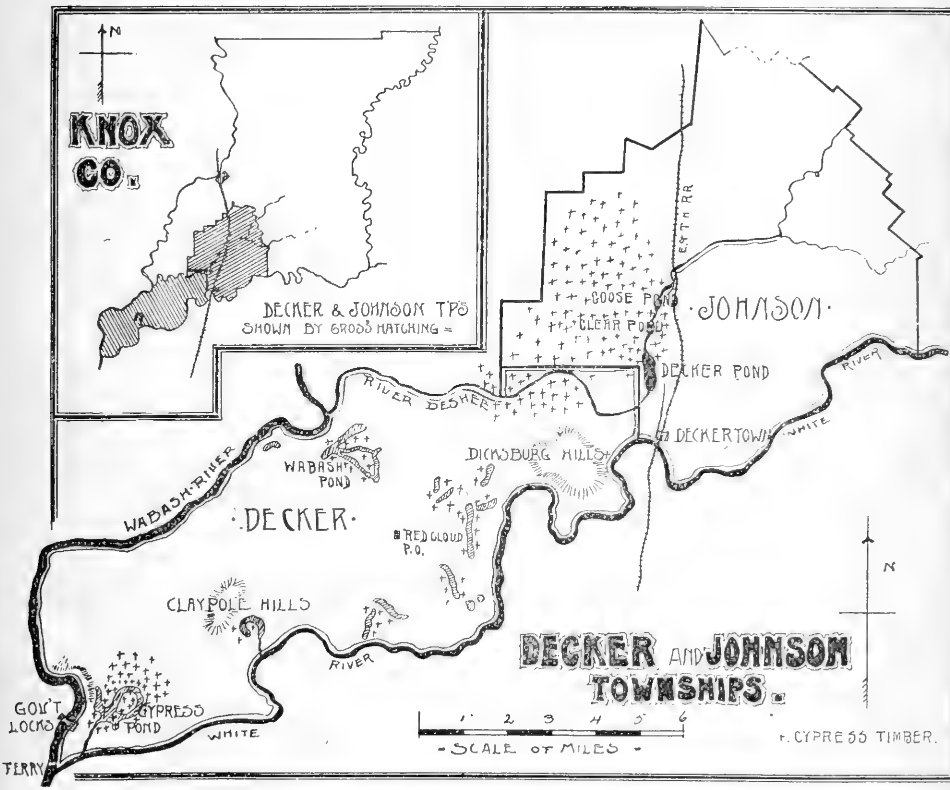
Below the graft the trunks were about seven or eight inches apart and nearly parallel; above they diverged slightly.

The lack of measuring appliances at the time of the examination prevents anything but an approximation of dimensions.

Notes on the Cypress Swamps of Knox County, Indiana.

By John S. Wright.

It has been stated frequently that in Knox County, Indiana, are the northernmost cypress swamps. According to the manual of Britton and Brown, the range of the cypress *(Taxodium distichum* (L), L. C. Rich) is given as "Delaware (possibly in southern New Jersey), Florida, west to Texas, north in the Mississippi Valley region to southern Indiana, Missouri and Arkansas." Gray's Manual also gives this range. The latitude of the swamps of Knox county is about 38° 30′, so that if cypress ranges over any considerable portion of southern Delaware it is in a higher latitude than that of Knox county, since Delaware extends from about 38° 28′ to about 39° 50′. Cypress of New Jersey would also be above this latitude, since Cape May, the most southern point, is about 38° 50′. While it may be that the cypress swamps of Knox county are the most northern characteristic growths of this kind, they certainly do not mark the northern limit of the range of the cypress. The swamps of Knox county are located, so far as I could learn, almost wholly in the townships of Decker and Johnson, both southern townships, and bounded on the south by the White River. Decker Township, forming what is known as the pocket of Knox county, is the triangular tract included by the Wabash and White rivers near their confluence. (See map.) A very large part of this territory is below extreme high-water level. Much of the southern and southwestern portions of Johnson, and a very considerable part of Decker Township, is inundated by the waters of the White and the Wabash when these streams are very high. In Decker Township there are three groups of hills, which are far above high water, viz., the Dicksburg and Claypole and a group of limestone hills along the Wabash River above the Government locks. Many farms in the interior are also above the level of the overflow.



In examining the swamps, comparatively little cypress is now found standing, though many of them are still heavily timbered with oaks and many other of our common forest trees. Nearly all the cypress of value as timber had been cut out in every swamp visited. In Johnson Township (see map) cypress was found to have been distributed over the area indicated. The territory is all very low, some of it boggy, though little water stands in the places indicated as ponds during the dry seasons, since the country has been partially ditched.

In the vicinity of Goose Pond and Clear Pond a few old trees were standing in clear open spaces once covered by water, but dry and good pasture land in September of 1897. These old trees were of large diameter at the ground, one measuring 15 feet at the surface of the ground. This expanded trunk contracted suddenly into a bench at a height of about

SKETCH FROM A PHOTOGRAPH.

four feet. The larger of the two diverging trunks ascending from this base was not over 3½ feet in diameter 8 feet above the ground. (See cut.)

Many of the scattering cypress trees of this swamp and the surrounding woodland were very tall and graceful, being fine representatives of the species. A lumberman estimated the height of several of these, by a rough but fairly accurate method, to be 110, 125 and 130 feet, with trunk diameter of 3½ to 4 feet, 4 feet above the ground.

In the work the southwestern portion of Johnson Township was pretty well covered, and cypress noted in the parts indicated on the map. Decker Township was traversed the entire length four times over three slightly different routes. Cypress was found sparsely distributed throughout the heavily timbered country in the vicinity of "Cypress Pond." At one time it was abundant there, but it has been nearly all cut out.

Lumbermen reported cypress in the following localities: "Wabash Pond," "Claypole Hills" and in low ground near White River east of "Red Cloud." "Wabash Pond" was not visited, and none was found in the vicinity of the Claypole Hills, although it is probably to be found there, as it is found in some other localities, represented by a few scattering trees, which have been left in the general destruction of this timber, occasioned by the demands for mill material. Oak is the most valuable and abundant timber now left in this region. A temporary railroad track runs from Decker (Deckertown) west and north about ten miles, and is used exclusively, or nearly so, in transporting logs and lumber from the mills and forests of that region to the mill at Decker and to the Evansville & Terre Haute Railroad at that point.

From an examination of the woodlands of Decker and Johnson Townships, it is evident that within recent years cypress was an abundant or predominant tree over territory aggregating 18 or 20 square miles. At present it is fast disappearing, and in all of the localities mentioned it is of minor importance in estimating the lumber resources.

Some Indiana Crow Roosts. By A. W. Butler.

When winter approaches, crows are observed to become much scarcer in many localities and very much more numerous in others. In October and November they begin to collect in places in companies of greater or less size and form "crow roosts." These are to be found in the woods in different parts of the country. Some are small, containing but a few hundred individuals. It is estimated that others contain as many as a quarter of a million, or more, crows. The Division of Ornithology and Mammalogy of the United States Department of Agriculture issued Bulletin No. 6, which contains the most complete account of the crow and its habits that has been published. It mentions a number of crow roosts in the United States. Only one, however, is noted from Indiana. This one was located near Irvington and was reported by Mr. W. P. Hay. In the course of other investigations I have gathered some information concerning crow roosts in and near this State. Those to be mentioned are very probably not all that will be found, but the list which I shall give will serve as a basis for an investigation of this interesting and important subject.

I mention the following which have been reported:

1. A roost near Richmond, Ind., where, prior to the winter of 1896-7, they roosted in large numbers about a mile and a half northwest of that city. Mr. W. S. Ratliff informs me that they remained all winter, but towards spring became restive and frequently changed their roosting place.

October 10th, 1896, a small company began to collect about two and one-half miles west of Richmond. On the 14th they changed to another locality, and then suddenly disappeared.

2. Mr. Ratliff informs me of a roost near Boston, ten miles south of Richmond. It may possibly be that this is the same company which formerly occupied the first mentioned roost.

3. Prof. W. P. Shannon informed me of a roost near Milroy, in Rush county, of which Mr. Lou Innis gave him the following information: He said the roost was in a soft maple swamp and that the crows sometimes came there by thousands. They were most abundant in roasting-ear time. In late years this roost has been almost broken up by the cutting of the trees and the persecution of the neighborhood boys. At times the farmers were obliged to make vigorous warfare against the birds to save their corn. According to the older residents, the roost has been located at the same place since their earliest recollection.

4. Prof. W. S. Blatchley informs me of a roost in a pine grove west of Bloomington, Ind.

5. The same gentleman also reports one near Terre Haute.

6. With the assistance of Prof. W. P. Shannon I have been able to obtain some facts concerning a roost in Shelby county. The members of this roost have been for a number of years past familiar objects to passengers through that county on the Big Four Railroad in daytime, when, in the morning, they might be seen wandering abroad in search of food and in the evening, returning to their roosts. Mr. Willard

Fields, of Fairland, says that for about six or seven years prior to 1891 or 1892 they occupied a grove of about fifteen acres adjoining the town of Fairland, but the boys disturbed them so that they sought another locality, and they have since established several different roosts. He says that their present roost is four or five miles southwest of Fairland. Mr. J. G. Perry, of London, Ind., says this roost is located between London and Brookfield, on the north side of the railroad, where they have roosted every winter for the past four years at least.

7. The roost near Irvington, as has been mentioned, was described by Mr. W. P. Hay February 24, 1890, in Bulletin No. 6, Division of Ornithology and Mammalogy, United States Department of Agriculture, pp. 18 and 19. In 1893 or 1894 Mr. George S. Cottman visited this roost and published an account of it in the Indianapolis News.

8. Mr. John S. Wright informs me there is a roost, which is not a large one, near Brown's Valley, Montgomery county.

9. Mr. Wright also tells me of a well-known roost near Camargo, Ill. There the crows gather by tens of thousands to roost in a scrub oak grove. It is said members of this company range nearly or quite across the first two tiers of counties in Western Indiana, more or less, nearly east of Camargo. Twenty or thirty years ago they are reported to have wandered by day as far as Terre Haute, Vigo county; Armiesburg and Montezuma, in Parke county, and Clinton, Vermillion county. There they obtained their food from the refuse of slaughter houses, which were prominent industries in those places.

10. Mr. J. A. Balmer, in 1889, wrote me of a roost numbering probably five hundred birds, to be found in the two cemeteries at Vincennes through the winter.

11. Mr. R. R. Moffett reports a crow roost at Slim Timber, White county, about twelve miles west of Brookston and twenty-one miles northwest of Lafayette. He estimates that one hundred thousand crows winter there.

12. Dr. J. T. Scovell informs me there is a roost between Lake Maxinkuckee and Logansport.

13. Mr. E. A. Schulze, of Ft. Wayne, reports a roost in School District No. 7, Bath Township, Franklin county, Indiana, in 1891, and says it existed for at least ten years previous to that date. He estimates that 1,000 crows were members of it.

In addition to those mentioned it is probable there is a roost to the northward of the Panhandle Railroad, not far from Knightstown, as great numbers of crows may be seen passing in that direction late in the afternoon at this season.

There is also probably a roost just over the line in Ohio, southeast of Franklin county, and east of Dearborn county. Mr. H. F. Bain one winter observed their coming in the morning and departing in the evening in southern Franklin county, and the direction from which they came, and in which they went indicated they belonged to a roost.

It is to be desired that all information possible be obtained concerning this, and any other roosts which are found within the State or the members of which range into Indiana, including the localities, dates of assembly and dissolution, foods, number of individuals composing the roost, according to the best estimates obtainable, and general habits of the birds and also the disposition of the people toward them.

NOTES ON CROW ROOSTS OF WESTERN INDIANA AND EASTERN ILLINOIS. BY JOHN S. WRIGHT.

Through the central part of Vermillion county, Indiana, during the late fall, winter and early spring, the crows may be observed during the afternoon in large flocks feeding over fields and working their way westward. During the shorter days this is noticed early in the afternoon. Through the part (central) of Vermillion county, Indiana, in which I have observed these movements, I know that it is thought that, during times other than the breeding season, these birds live in large numbers in well established roosts located in the small groves which are found in the prairies of Eastern Illinois.

In order to secure some definite information on this question last May I wrote Dr. Thomas Hood, of Dana, Vermillion county, Indiana, whose practice has familiarized him with the locality. In response he wrote me about as follows: "I have inquired concerning the roost in question (one reported at Camargo, Douglass county, Illinois,) of our older citizens. They have each heard of it, and some say there are more places than one where the crows are in the habit of congregating for the night in the little strips of scrubby oaks which grow along the small drains of the prairie to the west of here.

"One locality south of Metcalf, Vermillion county, Illinois, and west of Edgar Station, Edgar county, Illinois, is mentioned. Another farther west, north of Newman, Douglass county, Illinois, is also mentioned.

"It is said that the crows are quite pugnacious if any one invades the roost to do them harm, and are able to make it unpleasant for the invader. The farmers do not molest them, as they do not feed or do any damage to the crops anywhere near the roost."

In June last I was in Dana, Indiana, with the intention of visiting a roost which I heard was located at Hume, a station on the I., D. & W. Railroad, in Vermillion county, Illinois, about nineteen miles west of the State line, but learned of Mr. D. V. Bradley, of "The Hume Record," with whom I talked by telephone, that it would be useless to visit the roost at that time, as the crows were all nesting in the timber lands of the country over which they fed (parts of Edgar and Vermillion counties, Illinois, and Vermillion county, Indiana), and would not again congregate at the roosting place until about October, when the nesting season would be over. Mr. Bradley stated that several years ago these crows, which number many thousands, roosted about two miles north of Hume. Being molested and driven from that point, they established a roost in a maple grove (on the farm of John Hardin), southeast of Hume (distance not stated), and being again disturbed, they moved to a grove across a slough, about one-half a mile north of Hume, at which point they were last winter.

A similar roost is reported at Camargo, Douglass county, Illinois, about thirty-two miles west of the State line, on the I., D. & W. Railroad. Years ago it was within sight of the railroad.

Mr. George M. Gossett, formerly residing near or in Edgar, Edgar County, Illinois, about ten miles west of the line, reports a large roost near that place.

Several old citizens of Helt Township, Vermillion county, Indiana, (James Kauffman, Richard Gilmore and others), report that about twenty or twenty-two years ago a large roost existed in the southern part of the township in some of the pieces of timber along the edge of the prairie and a few miles west of the Wabash River (about seven miles north and west of Clinton). The persons who had known this roost state that the crows fed up and down the Wabash River and to the east of it into Parke county, foraging around the packing houses located at the various towns, particularly Terre Haute (twenty or twenty-two miles south) and Armiesburg, in Parke county, on the old Wabash & Erie Canal (seven or eight miles distant) west and north.

A roost is reliably reported to have existed some eight years ago about one mile northwest of Brown's Valley, Montgomery county, Indiana (about thirteen miles southwest of Crawfordsville). This is said not to exist there at present.

The same person, a Rev. Mr. Kendall, of Dana, formerly of Brown's Valley, who reported the Brown's Valley roost, stated that another was located about one mile north of Guion (the crossing of the T. H. & L. Division of the Vandalia and the I., D. & W. Railroad) in the timber not far from Little Raccoon Creek.

The last two roosts mentioned seem not to have been as large as those of Eastern Illinois.

Those acquainted with the Illinois roosts state that the crows are not in the habit of feeding near the roost, though they are some times destructive to corn in the roasting-ear stage.

The roosts are very noisy. The birds will often alight two and three deep on limbs, bending the branches and splitting the tree tops. The settling down for the night is accompanied by cries and caws, crashing of limbs and the continuous flutter and flapping of wings as the birds move about to find vacant perches.

Nearly all with whom I have talked of these roosts state that the crows will defend the roost against an ordinary intrusion by a single person or by a few persons, showing great pugnacity. However, when a general onslaught is made and the battle seems too much, they arise and move away. They have been known to ruin fields of corn which had attained a height of several feet on alighting after a flight from such attacks.

Brunnich's Guillemot (Uria lomvia) an Addition to the Birds of Indiana. By A. W. Butler.

The effects of storms upon birds are always of great interest. It makes no difference whether this is the flight of migrants during a dark and stormy night against the protection of the lights of a lighthouse or of a lighting tower, or the death-dealing effects of a chilling storm upon our great lakes at the height of the migrating season, or the bewildering influences of a wide-extended storm area, which causes these wanderers to lose their way or scatters birds far from their natural homes. These conditions are so sudden and their results are so unusual and in many cases almost entirely unexpected, that it is but rarely that one can take the opportunity or find available the material for very satisfactory study of the conditions and results.

It has been my good fortune, since our last meeting, to have received some very interesting information bearing upon the dispersal of birds by storms. To one of these I shall refer at this time. Brunnich's Murre, a bird of the North Atlantic, which is seldom found far south of New England, and is never believed to have been authentically reported far from the ocean, has been taken in such localities as indicate that just before the middle of December, 1896, some great storm must have driven a number of these birds far inland and dispersed them far south along the Atlantic coast. They were found in Michigan, Western Indiana, in Ohio, and as far south as South Carolina.

While at Indianapolis the last week in December, 1896, Prof. W. S. Blatchley, State Geologist of Indiana, told me of a strange bird that had been taken near there. His information was that it was some sort of a Guillemot. I learned it had been sent for mounting to Mr. J. E. Beasley, at Lebanon, Ind., and that the same taxidermist had received others.

Upon my return home I found a letter from my friend, Mr. Ruthven Deane, informing me that Mr. F. M. Woodruff, of the Chicago Academy of Science, had received a Murre from Indiana. A few days later this information was supplemented by a letter from Mr. Woodruff, informing me that the specimen was *Uria lomvia.*

In looking over my accumulated mail I found a report from Mr. A. W. Hamilton, Zanesville, Ind., of the capture of a specimen near there. Prof. E. S. Moseley wrote me of the capture of four specimens near Sandusky, O., and Mr. J. E. Beasley in a note said he had received four specimens. The total number of records received in a few days was ten. I give herewith data concerning the specimens.

The first specimen mentioned above was brought to Mr. F. M. Noe, a dealer in natural history specimens, of Indianapolis, Dec. 17, 1896, by a boy, who told him it had been taken alive the preceding Sunday, Dec. 13, near Schofield's old mill, on Fall Creek, about seven miles north of that city. The specimen is now in the State Museum at the Capitol. The specimen reported by Mr. Hamilton was taken by Mr. J. W. Roe, of Zanesville, Ind., in the northern part of Wells County, Dec. 18, 1896. It was first observed slowly moving about in an open field and was shot at long range. This bird is now in my collection.

On December 28, Mr. J. E. Beasley wrote me that he had in his possession four of these birds from four different Indiana localities. One was the specimen sent by Mr. Noe. Another was brought to him alive by Mr. David Johnson, from Hazelrigg, Boone County, December 18. Mr. A. W. Beck, of Hazelrigg, informs me that it was captured alive about December 15. Mr. Johnson was driving along the road near that town and saw the bird in a field near by. He caught it and kept it two or three days. It was a persistent diver when put into the water; would offer to fight when approached, and did not make much effort to get away.

The third bird was sent to him by Mr. J. F. Warner, of Fowler, Benton County. Mr. Warner has written me the bird was captured on the road about three miles west of Fowler by a teamster, whose name is unknown to him, about Dec. 20. He adds that he never saw but one other bird of this kind. It was caught near Reynolds, White County, Indiana, by Mr. Linck, a night watchman on the Panhandle Railroad, in March, 1869. He adds: "It lived three or four days and died in my possession, but was not preserved."

The fourth was received by the taxidermist, about Dec. 20, from Mr. A. C. Littleton, Pickard, Ill. It was caught by Mr. Abel Christy, about three-fourths of a mile north of that place, Dec. 10, and was kept alive until it was sent to be mounted, but died on the road.

Prof. E. L. Moseley, Sandusky, Ohio, informs me that the four specimens he reported were taken within twenty miles of Sandusky, Dec. 19, 1896.

A fine adult male was taken by a twelve-year-old boy on the Iroquois River, Iroquois Township, Newton County, Ind., one and a half miles from Foresman, near what is known as the old Indian Ford, Dec. 31, 1896. It was shipped to a firm on South Water street, Chicago, where Mr. F. M. Woodruff obtained it, and it is now in his collection. He obtained the information given above from the Postmaster at Foresman, Ind., and kindly sent it to me.

The "Bulletin" of the Michigan Ornithological Club, January, 1897, p. 10, refers to a Murre identified as *Uria troile*, which Mr. N. A. Wood informs me is shown by re-examination to be *Uria lomvia*. The specimen is an adult male and was shot from a flock of several near Gibraltar, Mich., Dec. 26, 1896, by some duck hunters. The specimen is, I understand, in the museum of the University of Michigan at Ann Arbor. In the same publication, on page 8, is a reference to two "Black Guillemots" taken at the St. Clair Flats, near Detroit, Mich. From a letter received from Mr. W. A. Davidson, Detroit, Mich., I gather that one of the two birds noted is in the possession of Mr. C. Havens, of that city. The other belongs to a lighthouse keeper, whose name he does not know, at the St. Clair Flats. Evidently both specimens are *Uria lomvia*. It is possible a careful examination of the specimens will show that these also belong to this species. They were all taken within a few days. Only twenty-one days elapsed from the date when the first was obtained until the last was in the hands of a naturalist. This is its first record from Indiana, except that reported by Mr. Warner, which, unfortunately, is not verified by the specimen. It will be of interest to hear of other records of the occurrence of this species inland. It will be noted that there is a specimen preserved in a public museum in Indiana and in Michigan to verify the records from those States.

Notes on the Birds Observed in the Vicinity of Richmond, Wayne County, Indiana. By Alden H. Hadley.

The following is a list of the birds observed in the vicinity of Richmond, Wayne County, Indiana, together with some brief notes relative to their distribution, abundance and migrations. It is not to be supposed that this list is complete, though I believe it represents as many species as can ordinarily be observed in the course of one year, including especially the fall and spring migrations.

There are obviously many species which are comparatively rare in any given locality, and it is on this account that the necessity arises for observations extending over a period of several years before a complete catalogue can be obtained.

Again, every ornithologist has observed that a certain bird hitherto unreported and considered as rare may suddenly become quite common and then disappear as mysteriously as it came. Such facts combine to increase the difficulty of ever obtaining a list of all the birds which may, at some time or other, pass through a given locality. The difficulty is further heightened when it is remembered that some of the migratory birds pass by us without so much as lighting, and in the night-time at that.

While speaking of migrations, it might here be noted that some of those species which are comparatively uncommon or rare during the fall migrations are common or abundant during the spring migrations, and vice versa. To my knowledge a satisfactory explanation of this has never been given, though it would seem probable, amongst those species where this is true, that there is a difference between the lines of migration pursued by the fall migrants and those of spring.

Again there are other species which are sometimes resident and sometimes migratory, being swayed back and forth by extremes of temperature. Also those species some individuals of which are always resident and some always migratory. But these facts will be duly exemplified in the list which is now submitted.

1. *Podilymbus podiceps* (Linn.) Pied-billed Grebe.

Found occasionally on our streams and ponds.

2. *Urinator imber* (Gunn.) Loon.

Sometimes observed during migrations. One was killed on the reservoir, east of Richmond, on April 8, 1897.

3. *Hydrochelidon nigra surinamensis* (Gmel.) Black Tern.

During the heavy freshet of last summer (1896) a flock of these birds was observed in the neighborhood of Thistlewaithe's pond, north of Richmond.

4. *Anas boschas* (Linn.) Mallard, "Wild Duck."

Common during the migrations, when flocks of them frequently settle down for several days.

5. *Anas discors* (Linn.) Blue-winged Teal.

A moderately common migrant.

6. *Branta canadensis* (Linn.) Canada Goose.

A common migrant; arrives generally about the first of March and begins to pass through on its southward flight during the latter week in October.

7. *Botaurus lentiginosus* (Montag.) American Bittern.

A by no means common bird in this vicinity, but often found during the migrations.

8. *Ardea herodias* (Linn.) Great Blue Heron.

A rather uncommon bird in this locality and I have yet to find it breeding.

9. *Ardea candidissima* (Gmel.) Snowy Heron.

Stragglers are occasionally noted. One this spring (1897) on April 27.

10. *Ardea virescens* (Linn.) Green Heron.

An abundant summer resident; arrives about April 15 and begins to nest in the early part of May.

11. *Porzana carolina* (Linn.) Sora.

I have observed two individuals of this species here, on April 11 and 20. It is probable, however, that it may have been the same individual, as the second one seen was observed at the same spot where the first had been seen.

12. *Philohela minor* (Gmel.) American Woodcock.

Not very common, but occasionally noted during the migrations.

13. *Gallinago delicata* (Ord.) Wilson's Snipe.

A rather common migrant; arrives during the latter part of March.

14. *Totanus solitarius* (Wils.) Solitary Sandpiper.

A moderately common bird during the migrations; arrives generally during the latter part of April.

15. *Actitis macularia* (Linn.) Spotted Sandpiper.

A common summer resident. Especially abundant during the latter part of the summer and early fall, at which time those mostly seen are birds of the year.

16. *Ægialitis vocifera* (Linn.) Killdeer.

A common summer resident, arriving very early in the spring, generally about the first of March.

17. *Colinus virginianus* (Linn.) Bobwhite.

A moderately common resident, though growing alarmingly scarce for the last year or two, and it would seem inevitable that unless legislation shall provide other measures for its protection it will ere long become well nigh extirpated in many localities.

18. *Zenaidura macroura* (Linn.) Mourning Dove.

An abundant bird and irregularly migratory.

19. *Cathartes aura* (Linn.) Turkey Vulture.

An abundant bird; irregularly retiring southward on the approach of winter and reappearing about the middle of March.

20. *Accipiter velox* (Wils.) Sharp-shinned Hawk.

A moderately common hawk, and one of the few that are an unmitigated nuisance, preying almost exclusively upon birds and poultry.

21. *Accipiter cooperi* (Bonap.) Cooper's Hawk.

A moderately common hawk in this vicinity.

22. *Buteo borealis* (Gmel.) Red-tailed Hawk.

Moderately common, though never abundant. The hawk most frequently, and very often falsely, accredited with all the barnyard depredations.

23. *Haliæetus leucocephalus* (Linn.) Bald Eagle.

Occasionally reported as passing through.

24. *Falco sparverius* (Linn.) American Sparrow Hawk.

An abundant hawk.

25. *Pandion haliætus carolinensis* (Gmel.) Osprey.

Occurring casually along the White Water, though I have no record of it breeding.

26. *Syrnium nebulosum* (Forst.) Barred Owl.

A moderately common, or rather uncommon, resident.

27. *Megascops asio* (Linn.) Screech Owl.

An abundant owl. Resident.

28. *Bubo virginianus* (Gmel.) Great-horned Owl.

A tolerably common resident.

29. *Nyctea nyctea* (Linn.) Snowy Owl.

Occasionally straggling down during winter.

30. *Coccyzus americanus* (Linn.) Yellow-billed Cuckoo.

A remarkably abundant bird in this vicinity; more abundant, I believe, than I have ever observed it elsewhere. Arrives usually during the first week in May and becomes common about a week after the first migrants have put in their appearance.

31. *Ceryle alcyon* (Linn.) Belted Kingfisher.

An abundant bird along all our creeks and brooks, and only forced southward by their freezing over. I had thought that during the past winter (1896–97), when the temperature went down as low as 18 or 20 degrees below zero, they certainly had all left our streams and retired to the South. I was, however, informed by a boy who works near a mill race that during the coldest days, when the river was frozen over to a thickness of several inches, he observed a pair of these birds which frequented the mill race to avail themselves of the flood of water which at regular intervals was turned into the race from the ice-bound river, by this means being enabled to obtain at least enough of their finny prey to furnish them with a tolerable subsistence. An instance of this kind has never come under my notice before, though I doubt not that *Alcyon* often avails himself of such agencies when stern nature would have ordered him otherwise.

32. *Dryobates villosus* (Linn.) Hairy Woodpecker.

A common resident.

33. *Dryobates pubescens* (Linn.) Downy Woodpecker.

An abundant resident.

34. *Sphyropicus varius* (Linn.) Yellow-bellied Sapsucker.

A moderately common migrant. Not known to brëed. Was first noted this spring on April 7, and was first noted during fall migrations on September 26.

35. *Melanerpes erythrocephalus* (Linn.) Red-headed Woodpecker.

An exceedingly abundant bird and irregularly migratory. In years when beechnuts are unusually abundant I have found the woods literally alive with these birds as late as the last week in December. Then upon the advent of prolonged spells of severe weather, they retreat southward, and again put in their appearance a few days after the middle of April.

36. *Melanerpes carolinus* (Linn.) Red-bellied Woodpecker.

A by no means abundant, though a tolerably evenly distributed, resident.

37. *Calaptes auratus* (Linn.) Flicker.

An abundant bird; mostly migratory. Unlike other woodpeckers, it is fast becoming a ground-feeding bird and losing some of the typical picarian characters.

38. *Astrostomus vocifernus* (Wils.) Whippoorwill.

A moderately common, or rather uncommon, summer resident.

39. *Chordeiles virginianus* (Gmel.) Night-Hawk.

A common summer resident; arrives about May 20. Most noticeably abundant, however, toward the latter part of the summer and early fall, when large flocks of them may be seen of afternoons performing their wonderful aerial evolutions.

40. *Chætura pelagica* (Linn.) Chimney Swift.

An abundant summer resident; arrives about April 12 and departs southward in early fall.

41. *Trochilus colubris* (Linn.) Ruby-throated Humming-bird.

A common summer resident; arrives during the first week in May.

42. *Tyrannus tyrannus* (Linn.) King-bird.

An abundant summer resident; usually puts in its appearance about April 24.

43. *Sayornis phœbe* (Lath.) Phœbe.

A common summer resident; arrives during the last week in March.

44. *Contopus virens* (Linn.) Wood-pewee.

An abundant summer resident; arrives usually during the last week in April, and I have last noted it on October 8.

45. *Empidonax flaviventris* (Baird.) Yellow-bellied Flycatcher.

A moderately common migrant.

46. *Empidonax minimus* (Baird.) Least Flycatcher.

An abundant migrant. Was first noted this spring (1897) on April 22.

47. *Myiarchus crinitus* (Linn.) Crested Flycatcher.

An abundant summer resident; usually arrives about the same time as *minimus*. First noted this season on April 24.

48. *Octocoris alpestris* (Linn.) Horned Lark.

An abundant winter resident; first flocks generally arrive during the latter part of November, and all have retreated northward by the middle of February, seldom later.

49. *Cyanocitta cristata* (Linn.) Blue Jay.

An abundant resident.

50. *Corvus americanus* (Aud.) American Crow.

An abundant resident; nests early in April.

51. *Dolichonyx oryzivorus* (Linn.) Bobolink.

A casual summer resident. During the summer of 1897 as many as eight or ten pairs were noted. It seems to be quite local in its breeding habits here. The majority of those seen were found in a meadow about three miles northeast of Richmond.

52. *Molothrus ater* (Bodd.) Cowbird.

An abundant summer resident, arriving as early as March 26, though not becoming common until later.

53. *Agelaius phœniceus* (Linn.) Red winged Blackbird.

An abundant summer resident. I have first noted it as early as March 10, and have last noted it in the fall as late as October 30. Breeds in the various small marshy meadows and around the ponds in the vicinity of Richmond.

54. *Sturnella magna* (Linn.) Meadow Lark.

An abundant summer resident, arriving early and staying late. This season I first observed them on February 16.

55. *Icterus spurius* (Linn.) Orchard Oriole.

A moderately common bird during the breeding season, building its nest of dried grass intricately interwoven. Arrives during the latter part of April. Retires southward during the last of August.

56. *Icterus galbula* (Linn.) Baltimore Oriole.

A common summer resident, arriving this spring (1897) on the 24th of April. A pair nests each season on the campus of Earlham College.

57. *Quiscalus quiscula æneus* (Ridgw.) Bronzed Grackle.

A very abundant summer resident, arriving as early as February 21.

58. *Carpodacus purpureus* (Gmel.) Purple Finch.

A common migrant; rather spasmodically abundant, but usually more numerous during the spring migrations. Arrives during the spring migrations about March 20, and the last flocks have usually disappeared northward by April 11. I have first seen it on October 22 during the fall migrations. Comparatively few birds are seen with the typical male plumage which, as Burroughs says, gives the bird the appearance of having been dipped in pokeberry juice. I have found the Purple Finch wintering very abundantly in North Carolina. They preferably seek a country clothed in cedars and conifers.

59. *Spinus tristis* (Linn.) American Gold-finch.

A common and irregularly migratory bird. Nests late in summer.

60. *Spinus pinus* (Wils.) Pine Siskin.

An abundant migrant. *Much more* abundant during spring than during fall migrations. Last fall ('96) I only noted one individual, while during the following spring it was *remarkably abundant*, appearing about March 20 and not entirely disappearing northward until May 17.

61. *Poocætes gramineus* (Gmel.) Vesper Sparrow.

A common summer resident; arrives about March 16, becoming common a week later, when their songs may be heard in the fields and along the hedges.

62. *Ammodramus sandwichensis savanna* (Wils.) Savanna Sparrow.

I have only observed two individuals of this species here, one on March 26 and the other on April 29. It is by no means a common bird here.

63. *Chondestes grammacus* (Say.) Lark Sparrow.

An uncommon bird in this vicinity, its regular range being farther to the westward, and it being rather a bird of the prairies. During the spring of 1897 I observed two birds of this species, on April 30 and May 13.

64. *Zonotrichia leucophrys* (Forst.) White-crowned Sparrow.

An abundant migrant, arriving later in the spring than *albicollis*. Was first observed this season on April 30 and had vanished northward by May 16. During fall migrations I have first noted it on October 15.

65. *Zonotrichia albicollis* (Gmel.) White-throated Sparrow.

An abundant migrant, arriving about April 15 and disappearing northward about the same time as *Leucophrys*. First arrives during fall migrations about Oct. 8 and vanishes southward by the middle of November.

66. *Spizella monticola* (Gmel.) Tree Sparrow.

An abundant winter resident; arrives about November 1 and disappears northward again by the last of March.

67. *Spizella socialis* (Wils.) Chipping Sparrow.

A common summer resident; arrives about April 1st.

68. *Spizella pusilla* (Wils.) Field Sparrow.

A common summer resident; was first seen this spring on March 26th.

69. *Junco hyemalis* (Linn.) Slate-colored Junco.

An abundant winter resident; arrives towards the latter part of September. All have vanished northward by the 26th of April, or thereabouts.

70. *Melospiza fasciata* (Gmel.) Song Sparrow.

A common resident and one of the few birds whose song may be heard almost every month in the year.

71. *Melospiza georgiana* (Lath.) Swamp Sparrow.

A common though not abundant migrant; arrives about the middle of April and all have passed northward by about May 5. I have first noted it during the fall migrations on October 15.

72. *Passerella iliaca* (Merr.) Fox Sparrow.

An abundant migrant and the largest of the sparrows; arrives about March 26th and vanishes northward by the middle of April. I have first observed it during the fall migrations on October 8, and last on October 30.

73. *Pipilo erythropthalmus* (Linn.) Tohwee.

A common resident.

74. *Cardinalis cardinalis* (Linn.) Cardinal.

A common resident.

75. *Habia ludoviciana* (Linn.) Rose-breasted Grosbeak.

A moderately common or rather uncommon migrant; have only observed it during the spring migrations. First observed it on April 26 and last saw it on May 10. Probably not more than 10 individuals in all.

76. *Passerina cyanea* (Linn.) Indigo Bunting.

An abundant summer resident; put in its appearance this spring on April 25. Disappears southward during the latter part of September.

77. *Spiza americana* (Gmel.) Dickcissel.

A common summer resident, nesting in the meadows. Arrives during the first week in May.

78. *Piranga erythromelas* (Vieill.) Scarlet Tanager.

A common bird during the spring migrations; was first observed this season on April 23 and had disappeared northward by the 10th of May. The males and females consort together throughout the migrations.

79. *Progne subis* (Linn.) Purple Martin.

An abundant summer resident, arriving about the last week in March and becoming common a week later.

80. *Petrochelidon lunifrons* (Say.) Cliff Swallow.

A common summer resident.

81. *Chelidon erythrogaster* (Bodd.) Barn Swallow.

An abundant summer resident; was first noted this season on April 22.

82. *Clivicola riparia* (Linn.) Cliff Swallow.

A very uncommon, or scarce, summer resident in the immediate vicinity of Richmond.

83. *Ampelis cedrorum* (Vieill.) Cedar Waxwing.

An abundant and irregularly migratory bird, and gregarious. Probably resident some years. A bird that wanders widely about, largely according to food supply. It is, however, probably most abundant during spring and fall. It nests rather late in summer.

84. *Lanius borealis* (Vieill.) Northern Shrike.

A casual winter resident.

85. *Lanius ludovicianus* (Linn.) Loggerhead Shrike.

A rather uncommon summer resident. I first noted it this season on March 22. Those specimens which I have taken here seem to more nearly grade into *ludovicianus* than into *excubitorides*.

86. *Vireo olivaceus* (Linn.) Red-eyed Vireo.

An abundant summer resident, arriving during the latter part of April. It disappears in the fall by the middle of September. It is an untiring songster, and one of the few birds whose warblings may be heard in the woodland during the heat of noonday.

87. *Vireo gilvus* (Vieill.) Warbling Vireo.

An abundant summer resident and an untiring songster, singing from the time of its arrival in the spring until the first weeks of September. I first noted it this season on April 22.

88. *Vireo flavifrons* (Vieill.) Yellow-throated Vireo.

A moderately common bird for the space of a few days during the spring migrations. I have failed to observe it during the fall migrations. It is also probable that some individuals of this species may nest here. I have taken a male on June 26 and have failed to note any more from that time until the following spring. It arrives during the spring migrations about the same time as *gilvus* and I failed to observe any this season later than April 24. It is a large, stoutly built bird for a vireo.

89. *Vireo solitarius* (Wils.) Blue-headed Vireo.

A rather uncommon migrant. During the spring of 1897 I observed but two individuals; on April 26 and 30. During the preceding fall migrations I took one specimen on September 25.

90. *Vireo noveboracensis* (Gmel.) White-eyed Vireo.

I have only taken one specimen here, and that on August 4.

91. *Mniotilta varia* (Linn.) Black and White Warbler.

An abundant migrant. Was first observed this season on April 17, though not becoming common until the last of April and disappearing northward by May 16. During the fall migrations I have first noted it on September 12 and last on September 26.

92. *Helminthophila pinus* (Linn.) Blue-winged Warbler.

A rather rare migrant. I observed but one specimen during the spring of 1897 and it was taken on April 24. During the preceding fall I took but one specimen, and that on September 28.

93. *Helminthophila chrysoptera* (Linn.) Golden-winged Warbler.

Another rare migrant. I noted but two this spring. Both were seen on April 22.

94. *Helminthophila ruficapilla* (Wils.) Nashville Warbler.

A very abundant warbler during the spring migrations. I have first noted it on April 24 and last saw it on May 10. This is a warbler which preferably keeps to the tall timber and is more difficult of identification on that account.

95. *Helminthophila celata* (Say.) Orange-crowned Warbler.

A rather rare migrant. But two were seen during the spring of 1897. On May 1 and 4.

96. *Helminthophila peregrina* (Wils.) Tennessee Warbler.

An abundant fall migrant, appearing during the first of September and vanishing southward by the last of the same month. The flight and habits of this species are very similar to *ruficapilla*.

97. *Dendroica tigrina* (Gmel.) Cape May Warbler.

A very rare migrant. I have noted one on September 30.

98. *Dendroica æstiva* (Gmel.) Summer Warbler.

A common summer resident; arrives about the 20th of April and becomes quite common a few days later. Disappears southward in early fall.

99. *Dendroica cœrulescens* (Gmel.) Black-throated Blue Warbler.

A common spring migrant, but rather scarce during fall migrations. Arrives during first week in May and disappears northward by about May 10. Hence it lingers for a much less length of time than some of the warblers which may be found from almost the middle of April until the middle of May. One of the later warblers to arrive during the fall migrations.

100. *Dendroica coronatæ* (Linn.) Myrtle Warbler.

An abundant migrant. One of the latest to arrive in fall and one of the earliest in spring. I have first noted it in the fall on September 26 and first during the spring migrations on April 22. I have found this bird wintering very abundantly both in North Carolina and Florida, and in the first-mentioned State it apparently seemed little discommoded by the deep snows which were of frequent occurance during that winter.

101. *Dendroica maculosa* (Gmel.) Magnolia Warbler.

One of the most abundant of any of the warblers during the migrations and about equally abundant during each of the migrations. It is, too, one of the later warblers to arrive in the spring. I have first noted it on May 8 and last on May 16. During the fall migrations it puts in its appearance about September 6 with a number of other warblers, such as the Black-throated Green, the Blackburnian, the Tennessee, the Redstart and the Chestnut-sided. I have last observed it on October 3, though quite a time before this the majority of them have departed southward.

102. *Dendroica pensylvanica* (Linn.) Chestnut-sided Warbler.

A common migrant; more abundant during the spring than during the fall migrations. Arrives about May 6 or 7, and vanishes northward by May 16. In the fall migrations it arrives during the first week in September.

103. *Dendroica castanea* (Wills.) Bay-breasted Warbler.

A rather uncommon migrant; more frequently to be observed during spring migrations, when it arrives during the first week in May. I have first noted it in the fall on September 12.

104. *Dendroica striata* (Forst.) Black-poll Warbler.

This is the bird which brings up the rear guard of the great army of warblers during their northward flight, and was first seen this spring on May 19, being quite common for a few days and then disappearing. It prefers the tops of the taller trees, and may be seen slipping along the branches much after the fashion of the Black and White Creeper, and occasionally uttering its rather weak note, which somewhat resembles that of the Chipping Sparrow, and is very deceptive as to telling the whereabouts of the bird.

105. *Dendroica blackburniæ* (Gmel.) Blackburnian Warbler.

An abundant migrant. I have first noted it on April 22, though it does not become common until during the first week in May, and I have last seen it on May 19. The females do not become common until towards the middle of May. During the fall migrations it arrives about the 6th of September, and I have observed it as late as October 13.

106. *Dendroica virens* (Gmel.) Black-throated Green Warbler.

An abundant migrant, its migration schedule conforming to that of *blackburniæ*, though perhaps more individuals of *blackburniæ* linger later during the spring migrations than does *virens;* and this may also be true of the fall migrations. The larger number of these birds which one sees during the fall migrations, being birds of the year, have not yet attained to the exquisite loveliness of the adult males, and even the adult males lack to a great extent the beauty of plumage which characterizes them during the spring migrations. The black of the throat is partially concealed (especially in the case of birds of the year) by an intermixture of white, which gives the whole throat and fore parts a grayish cast.

107. *Dendroica vigorsii* (Aud.) Pine Warbler.

A rare migrant. Two were noted during the spring of 1897, on April 25 and 26.

108. *Dendroica palmarum* (Gmel.) Palm Warbler.

A moderately common, or rather uncommon, migrant; more frequently to be observed during the spring migrations. Was first seen this season on April 22 and last seen on May 16. During the fall migrations it may be looked for during the last of September or first of October.

109. *Seiurus aurocapillus* (Linn.) Oven Bird.

A common migrant; has not been found to breed. Arrives during the first week in May. During the fall migrations I have first observed it on September 7.

110. *Seiurus montacilla* (Vieill.) Water Thrush.

A moderately common migrant; arrives during first week in May. I have taken a female on July 25, and it possibly may be found to breed here.

111. *Geothlypis trichas* (Linn.) Maryland Yellow-throat.

A common summer resident, making the thickets and brakes resound with its lively notes. Arrives about April 24 and retires again southward by the middle or latter part of September.

112. *Icteria virens* (Linn.) Yellow-breasted Chat.

A common summer resident; usually arrives during the first week in May.

113. *Sylvania pusilla* (Wils.) Wilson's Warbler.

A rather uncommon spring migrant. I have first noted it on May 16, at the same time with *canadensis*, when a few days later both species disappeared northward. Neither of these two species were "common," though, during the few days that seemed to constitute their time for passing through, careful searching never failed to reveal two or three individuals of each species on each day that search was made.

114. *Sylvania canadensis* (Linn.) Canadian Warbler.

A rather uncommon spring migrant (I have yet to note either *canadensis* or *pusilla* during the fall migrations), conforming as regards its abundance and migration habits in all respects to *pusilla.*

115. *Setophaga ruticilla* (Linn.) American Redstart.

An abundant migrant; has been first noted on April 15, though not becoming common until the latter part of the month, and I have last seen it on May 19. I have taken a female on July 22, though this is quite unusual. During the fall migrations it arrives during the first week in September, and I have last noted it on September 26.

116. *Anthus pensilvanicus* (Lath.) American Pipit.

An abundant migrant; especially during the spring migrations, when I have first noted it on April 22, and last on May 4. It passes over in large straggling flocks, which occasionally light in the plowed fields or pastures. Its note is querulous and flight undulatory.

117. *Galeoscoptes carolinensis* (Linn.) Catbird.

An abundant summer resident; arrived this sea on on April 24.

118. *Harporhynchus rufus* (Linn.) Brown Trasher.

An abundant summer resident; first observed this season on March 30, though not becoming common for a week or two later.

119. *Thryothorus bewickii* (Aud.) Bewicks Wren.

A rather uncommon or rare bird in this locality and I have yet to find it breeding. I first noted it this spring on April 15, and observed three or four more individuals within the next two weeks and have seen no others since.

120. *Troglodytes aëdon* (Vieill.) House Wren.

A common, though not abundant summer resident, arriving this season on April 19.

121. *Troglodytes hyemalis* (Vieill.) Winter Wren.

A rather uncommon winter resident; arrives during tbe latter part of September and perhaps most individuals retire somewhat farther to the south. I have taken one specimen as late in the spring as May 5.

122. *Cistothorus palustris* (Wils.) Long-billed Marsh Wren.

I have observed but one individual of this species here, and it was taken on May 17.

123. *Certhia familiaris americana* (Bonap.) Brown Creeper.

An abundant migrant, and probably some individuals as winter residents. I have first noted them, during the fall migrations, on September 19. It is common from that time until the Christmas holidays, and if the winter is unusually "open" it may be seen at intervals throughout the entire winter. It, however, begins to be again common by the latter part of March and disappears northward by about April 20.

124. *Sitta carolinensis* (Lath.) White-breasted Nuthatch.

A common resident.

125. *Sitta canadensis* (Linn.) Red-breasted Nuthatch.

A common bird during late fall and early winter, with some individuals, probably, as winter residents. I have found it quite abundant during the latter part of December. Then, during a month or so of severe weather, they apparently nearly all retreat southward. I have last noted it in spring on May 3.

126. *Parus bicolor* (Linn.) Tufted Titmouse.

A common resident.

127. *Parus atricapillus* (Linn.) Chickadee.

A common resident, though not as abundant as *bicolor.*

128. *Regulus satrapa* (Licht.) Golden-crowned Kinglet.

A very abundant bird during fall and early winter, when for the most part it then retires to the southward, though it may sometimes be a winter resident.

It does not become common in spring until in the latter part of March or first of April, and all have retired northward by the end of April. During the fall migrations I have first observed it on September 25.

129. *Regulus calendula* (Linn.) Ruby-crowned Kinglet.

An abundant migrant, though hardly so numerous as *satrapa*. Arrives during the fall migrations perhaps a week before *satrapa*, and I have first noted it during the spring migrations on April 12, or about a week after *satrapa* appears, and it vanishes northward by May 1. This is not nearly so hardy a bird as the Golden-crowned, and it winters much farther to the southward.

130. *Polioptila cærulea* (Linn.) Blue-gray Gnatcatcher.

An abundant migrant and a rather rare summer resident; appeared this season on April 20, and had almost entirely passed on northward by the first of May.

131. *Turdus mustelinus* (Gmel.) Wood Thrush.

A rather uncommon summer resident, arriving this season on April 24.

132. *Turdus fuscescens* (Steph.) Wilson's Thrush.

A moderately common migrant; arrives about first of May.

133. *Turdus aliciæ* (Baird.) Gray-cheeked Thrush.

An abundant fall migrant; arrives about the middle of September and vanishes southward by the first week in October. I have yet to note it during the spring migrations.

134. *Turdus ustalatus swainsonii* (Cab.) Olive-backed Thrush.

A common migrant; more abundant in fall than in spring. This year I first noted it on April 23, and during the fall migrations I have first observed it on September 7, and it probably vanishes southward by the end of September.

135. *Turdus aonalaschkæ pallasii* (Cab.) Hermit Thrush.

An abundant and probably the most abundant thrush during the migrations; especially abundant in spring. First appeared this season on April 11, and I last saw it on May 18. On its southward flight it arrives during the latter part of September.

136. *Merula migratoria* (Linn.) American Robin.

An abundant summer resident; sometimes arrives as early as the 14th of February, and I have seen one as late as the 15th of December.

137. *Sialia sialis.* (Linn). Blue Bird.

Until within the last two or three years the Blue Bird was a common summer resident, but of late it has become almost a rarity. In fact, I failed to find it breeding here at all during the summers of '95 and '96, and have also failed this ('97). This rarity of the Blue Bird seems to be due to a severe spell of weather which occurred late in the spring of '95 (I believe it was) and which seemed to have worked great havoc not only in the case of the Blue Bird, but in some other instances. Still I have observed a few individuals during the migrations. I first noted it this spring on February 16, and probably altogether saw not more than twelve or fifteen individuals, and none of these remained with us. During the fall of '96 I failed to note it at all until on October 3, when I saw three. It yet remains to be seen whether after a few years nature will restore the equilibrium, and whether we will again have with us "the blessed Blue Bird, bearing the sky upon her back."

Notes on Indiana Heronries. By A. W. Butler.

The Great Blue Herons have for years been known to breed throughout the State, some places singly, at others in small companies, and again in considerable numbers. The Black-crowned Night Heron also breeds in heronries often near to or included in a nesting community of the last mentioned species. The Yellow-crowned Night Heron has only been reported as breeding in Knox county, where it attains its most northern breeding range. There Mr. Robert Ridgway found a community of about a hundred pairs nesting in the tall ash and sweet gum trees in a creek bottom near Monteur's Pond, in April, 1881. From the same vicinity Mr. Ridgway reported the Snowy Heron as breeding. The American Egret has been known to breed in the lower Wabash Valley. This was supposed to be its most northern breeding ground. Late in the summer, after the duties to the family were done they were supposed to wander farther to the northward, even reaching northern Indiana, Michigan and Ontario. This supposition seemed to be further borne out by the fact that there were, with very few exceptions, no records north of southern Indiana at the time of the spring migrations. It seemed quite unusual that they should wander northward in such numbers after the nesting season, consequently when I began to hear of one or two pairs being found in company with some colony of Great Blue Herons I was prepared to believe that if the right locality was found they might still be found breeding in some numbers in the northern part of this State, provided man's agency had not in some way destroyed them.

In Knox and Gibson counties Mr. Robert Ridgway reported heronries and noted the breeding of the Great Blue Heron, the Snowy Heron and the American Egret.

The American Egret, according to Mr. E. J. Chansler, breeds about Swan and Grassy Ponds, Daviess county.

Dr. J. T. Scovell reports that up to about 1881 or 1882 an extensive heronry of the American Egret was to be found in the Wabash bottoms about a mile west of Terre Haute.

Mr. J. F. Elliott, of New Harmony, informs me of a heronry at Hovey's Pond, Posey county, Indiana.

There is no record of any heronries in southeastern Indiana, but Dr. F. W. Langdon reports the Great Blue Heron as breeding along the Great Miami River, and in the neighboring parts of Ohio. Great Blue Herons have been reported as breeding in communities about ten miles south of Frankfort, in Clinton county, where they were noted by Mr. E. R. Quick, A small colony has also bred regularly at the mouth of the Tippecanoe River, above Lafayette, but when it was visited in May, 1897, but one or two pairs were found as lone remnants of the former community.

In Carroll county, Prof. B. W. Evermann speaks of two large heronries and one small one. He found as many as thirteen nests on one tree at one place and many other trees contained from three to ten nests each. (The Auk, October, 1888, p. 347). They are also reported to have formerly bred in colonies in Dekalb county, and investigation may show that they still do so.

Prof. A. W. Bitting reports a small heronry of about one hundred nests in southern Marshall county, on an island in the Tippecanoe River, at a locality called the Millpond. These were Great Blue Herons and he saw them in 1891. The same observer informs me that up to about 1890 there was a heronry of twenty-five or thirty nests of the American Egret in the Preston Swamp, in the same county, about two miles north of the one he first mentions.

There is a heronry of Great Blue Herons at Golden Lake, in Steuben county, and one at Wolf Lake, in Noble county, at each of which, according to Mr. H. W. McBride, occasional pairs of American Egrets have been found breeding.

Mr. R. B. Trouslot wrote me of a visit he made to "Cranetown," in Jasper county, in April, 1887. At that time he estimated there were thousands of Great Blue Herons nesting, and he saw a few American Egrets.

Mr. Ruthven Deane has favored me with several notes on a heronry called "Crane Heaven," near English Lake, Starke county, which, on March 18, 1894, he described as being occupied almost exclusively by Great Blue Herons, though quite a number of Black Crowned Night Herons always breed there.

Mr. Charles Dury, Cincinnati, has also informed me of a heronry at English Lake, which may be the same one.

Mr. J. G. Parker, Jr., of Chicago, informs me of a large colony of Great Blue Herons on the Kankakee River, nine miles south of Kouts, Indiana, where, on April 14, 1894, he reports the heronries filled with birds nesting. I am indebted to Mr. Parker, and also to Mr. F. M. Woodruff, of the Chicago Academy of Science, for notes furnished me concerning heronies in Porter county, Indiana. The accounts given refer to different dates, but whether the locality referred to is the same I am at present unable to say. Mr. Woodruff says that Mr. Charles Eldridge found the American Egret breeding at Kouts, Indiana, in May, 1885, and took a large number of their eggs. He found their nests in the same trees with those of the Great Blue Heron. He concludes: "I visited the heronries last June, 1896, and did not see a single specimen of the American Egret. In the fall of 1895 a terrible fire swept through the timber along the Kankakee River, which probably accounts for the depopulated state of the heronries."

Mr. Parker says Mr. George Wilcox found quite a number of American Egrets breeding in a heronry with the Great Blue Heron, near Kouts, Indiana, during May, 1895. Mr. Parker himself visited the place in the spring of 1896 and found only a few of the latter species occupying the heronry. He thinks the small number of birds found was due to the fact that a heavy fire swept through the timber in the fall of 1895.

Mr. C. E. Aiken, of Salt Lake City, Utah, who has made many valuable observations on the birds of northern Illinois and northwestern Indiana, as well as of Colorado, has very kindly given me an account of a visit to a heronry known as "Crane Heaven," occupying thirty or forty acres along the Kankakee River, some twenty miles above Water Valley. The time of his visit was in May, 1886. He says: "The locality is a timbered plot of ground, being submerged with twelve to eighteen inches of water at the time of our visit. At our approach, upon the discharge of a gun, the birds rose with a noise like thunder and hovered in hundreds above the tree-tops. They were of three species, the Great Blue Heron (*Ardea herodias*), the Black Crowned Night Heron (*Nycticorax nycticorax nævius*), comprising the majority, but the beautiful white plumage of the American Egret (*Ardea egretta*) was conspicuous through the feathered cloud, and these birds were quite numerous. Nearly all the trees throughout the belt were loaded with nests, those of the first two species named being found upon the same tree, but the latter birds appeared to build in little groups by themselves. We did not climb to examine the nests, but most of them appeared to contain young birds. Many of the trees were dead, apparently from the effects of the birds building and roosting upon them."

It is probable that some of these heronries along the Kankakee are referred to twice in the references I have made. At present I am unable to decide this matter. It is likewise very probable that there exists heronries on the Kankakee within our limits of which we know nothing. In this paper I have desired to bring to your attention, so far as I know it, the location of the former or existing heronries in Indiana in the hope that we may be able to locate all such sites as exist or have existed within the State.

This little article has served to acquaint you with the extension of the known breeding range of the American Egret northward for a distance equal to the whole length of the State of Indiana, and we find at the northern part of this breeding range that they have been found nesting in considerable numbers. Since this fact has been ascertained and we have been able to note the arrival of these birds at their breeding ground in the spring, we found their absence during the period of the spring migrations was only apparent, and that evidently their vernal pilgrimages are made at night, and consequently, although they may be found in numbers at their nesting sites, it is very rarely, indeed, that they are to be seen at this season of the year en route to their summer homes.

THE RECENT OCCURRENCE OF THE RAVEN IN INDIANA. BY A. W. BUTLER.

Of recent years the Raven has been supposed to be extinct in this State. The last Ravens of which I can learn in Franklin county were noted in 1868, and I know of none later than that from any point in southeastern Indiana.

Mr. C. E. Aiken informs me that a Raven was observed by him in Lake county in 1871.

Dr. A. W. Brayton, writing in 1879, informs us, "It frequents the sand hills along the shores of Lake Michigan from October until spring, eating the dead fish thrown up by the lake." (Transactions Indiana Horticultural Society, 1879, p. 129).

The winter of 1890-91 a number were taken in the eastern part of Allen county and adjacent parts of Ohio, and were brought to Mr. C. A. Stockbridge at Fort Wayne.

Mr. J. E. Beasley, in 1894, reported it as a rare winter visitor in Boone county, but he advises me that none have been seen there since that time.

In April, 1897, I was pleased to be informed by Mr. E. J. Chansler, of Bicknell, Knox County, that two persons had spoken to him of the recent nesting of the Raven in the cliffs of Martin county, and that one person claimed to have taken a nest and two eggs in 1894. He says that Mr. Cass Stroud, of Wheatland, informs him that Ravens are moderately common in the locality known as "Raven's Hollow," five miles south of Shoals. Mr. Chansler also ascertained that it was the belief that Ravens still nested at "Raven's Rock," in Dubois county. At my request, Mr. J. R. Wilson, County Superintendent of Schools at Jasper, Indiana, very kindly undertook to make inquiries regarding this matter. He personally knew that Ravens were found in that county up to five years ago—1892—and interested two teachers in the schools of that county in the question of its breeding at Raven's Rock, which was not far from their schools. Raven's Rock is a sandstone cliff seventy-five or eighty feet high, the top of which projects about thirty-three feet beyond its sides. It is situated between Dubois and Ellsworth. In the sides of the cliff are shelves which are almost inaccessible, and on these and in the crevices in the rock the ravens built their nests. These nests were roughly made of large weeds and even sticks, lined or felted with hair or wool. The ravens have not been observed there the past year, but were a year or two ago and regularly previous to that time.

The Raven, when flying, resembles a crow, but is much larger. They usually fly high and utter a harsh croak. It is claimed they were often seen as far as five miles from the rock. It is to be hoped that further investigations may be made showing the present status of the Raven as a bird of Indiana, and that specimens from this State may be secured for some of our collections before the birds shall have entirely disappeared.

Description of New Facial Muscles in Anura, with New Observations on the Nasal Muscles of Salamandridae.

By Henry L. Bruner.

[Abstract.]

The results of this investigation are presented under three sub-headings:

1. New observations on the nasal muscles of the salamanders. These muscles, which were described by the writer in the Archiv für Anatomie und Physiologie, 1896, consist in some cases of two muscles only (*a M. dilatator naris and a M. constrictor naris*). In other forms a third muscle (*M. dilatator naris accessorius*) is also present. These are smooth muscles, which arise wholly, or in large part, from the cartilaginous nasal capsule, or more definitely, from the margins of the fenestra rostralis.

The relation of the nasal muscles to the external nasal gland renders it highly probable that the contractions of the former produce a discharge of the glandular secretion upon the margin of the external nasal opening. The secure closing of the opening is thus facilitated.

Study of the development of the nasal muscles of the salamander demonstrates the fact that these muscles arise *in situ* in the mesenchyma. There is no migration similar to that of the striated facial muscles of higher vertebrates.

2. A description of new nasal muscles in Rana. Comparison of the frog and salamander shows that the former possesses a M. dilatator naris and also a second muscle, probably homologous with the M. constrictor naris. Both of these muscles, however, are degenerate in Rana and they have also undergone a change of function, so that they play only a very subordinate part in the closing of the external naris.

The development of these nasal muscles agrees with that of the nasal muscles of the salamander.

3. Description of a new muscle in the upper lip of Anura. This muscle, which I name Musculus labialis superior, lies in the soft overhanging upper lip, and has been observed in Rana, Bombinator, Hyla, Bufo and Alytes.

The M. labialis superior is composed of smooth fibres.

A Rare Species of Bascanion (B. ornatum). By Henry L. Bruner.

Masticophis ornatum, a snake of Western Texas, was described by Baird and Girard in 1853. Later these authors placed the type under the genus Bascanion and reduced it to a variety of B. taeniatum. Cope accepted this classification in his check list of the Batrachians and Reptiles of North America (1875), but in his later work on the snakes of North America (Proceedings of the National Museum, Vol. 14, 1891), he restores B. ornatum to the dignity of a species. This change, which was made in spite of resemblance in the coloration and scale formula of B. taeniatum and B. ornatum, was based on a great difference in the proportions of the head and in the breadth of the frontal in the two forms.

The available material for the study of B. ornatum has consisted, until recently, of two specimens belonging to the Smithsonian collections. Both of these were taken in West Texas, one near Howard Springs, the other between El Paso and San Antonio. A third specimen, which was recently found by the writer in the Franklin Mountains about twelve miles north of El Paso, Texas, has suggested the reflections contained in the present paper.

Through the kindness of Dr. Stejneger, who made the comparisons for me, I am able to state that the proportions of the head in the new specimen agree exactly with those of the specimen in the National Museum. Thus additional proof is furnished of the specific value of the characters attributed to B. ornatum. Similar evidence on this point is also to be obtained from a study of the coloration.

Cope has divided the genus Bascanion into two series of species, which are distinguished by the coloration of the young. In one group the young show a tendency to become cross-banded or spotted, as in B. constrictor, B. flagelliforme; in the other series the coloration is characterized by longitudinal stripes, as in B. laterale, B. taeniatum, B. schotti, B. semilineatum. In the latter series the stripes persist up to maturity, except in B. semilineatum, in which a trace only of stripes remains on the anterior half of the body of the adult. The cross-banded forms, on the other hand, all lose their bands at maturity, excepting B. flagelliforme, in which in the full-grown animal the bands are observable only toward the anterior part of the body.

Bascanion ornatum occupies a peculiar place in the genus because it combines the characters of the two series above described. All of the specimens of B. ornatum show both cross-bands and longitudinal stripes. However, here both the stripes and the bands persist in the adult. Of the two Smithsonian specimens, which are both a little more than five feet long, the cross-bands are more distinct in one specimen than in the other. In the new specimen, which is a young animal, only thirty-eight inches long, the cross-bands are also not strongly marked. It is clear then that in B. ornatum immaturity of the specimen is not associated with greater distinctness of cross-bands, as is the case in the B. constrictor and B. flagelliforme. In other words, the cross-bands are a fixed character of both adult and young of the species ornatum. These facts indicate that this species represents, with respect to coloration, the most generalized type in the genus; it is, therefore, the most primitive species, from which, on the one hand, the purely cross-banded series has descended on account of the obliteration of longitudinal stripes. The longitudinally striped series, on the other hand, has arisen because of the disappearance of the cross-bands.

On the Heart of Lungless Salamanders. By Henry L. Bruner.

[Abstract.]

In the American Naturalist for 1896 Hopkins announced the discovery of a septum atriorum in the heart of certain lungless salamanders; he omitted, however, in his description, the valve which, both in lungless forms and in those with lungs, guards the sinus-atrium opening.

A study of the heart of lungless salamanders had already been made by the writer before the paper of Hopkins came into my hands. Investigation of the same species used by Hopkins shows that the latter has described the sinus-atrium valve as a septum atriorum. I conclude, further, that no trace of a septum atriorum exists in the adult lungless salamanders studied by me (Plethodon cinereus, P. erythronotus, Desmognathus fusca, Salamandrina perspicillata, Spelerpes fuscus).

The conus arteriosus of certain lungless salamanders shows a spiral fold (e. g., Plethodon), but it seems to be absent in Desmognathus.

The Pulmonary Arch of Lungless Salamanders. By Miss Mae Woldt.

[Abstract.]

Although salamanders have long been studied, it was only recently discovered that some forms are lungless. Investigations have been made upon the mode of respiration and upon the modifications in the structure of the heart. As far as known, however, nothing has been published concerning the pulmonary arch. It is reasonable to suppose that the arch which, in amphibians, carries blood to the lungs would undergo more or less degeneration in the lungless salamanders. In the forms with lungs this arch also sends branches to the œsophagus. An investigation of lungless salamanders (Plethodon cinereus and P. erythronotus) shows that the pulmonary arch persists between the truncus arteriosus and the point of origin of the œsophageal branches; beyond this point it has disappeared. The pulmonary arch also sends branches to the skin. The salamander has, however, another skin artery, and it is not impossible that the disappearance of the lungs in the lungless forms finds its explanation in this double supply of blood to the skin. The functon of supplying other parts of the body was at least important enough to prevent the entire disappearance of the pulmonary arch in the lungless salamanders.

An Instance of Bird Ferocity. By Glenn Culbertson.

During last May John Gabel, a student in ornithology, reported the following observation: While riding near Hanover Mr. Gabel's attention was attracted by the fluttering of wings in an osage hedge by the roadside and by cries as of a bird in distress. On dismounting and approaching to within ten or twelve feet of the place for a closer inspection he observed a Loggerhead Shrike *(Lanius ludovicianus)*, impaling a Sparrow Hawk *(Falco sparverius)*, upon the thorns of the osage tree. The Shrike was accomplishing this by beating the Hawk with its wings and by striking it with its beak.

On Mr. Gabel's nearer approach the Shrike became frightened and flew to a tree near by. The Sparrow Hawk remained impaled on the hedge thorns and continued to flutter frantically until it was on the point of being captured, when it was able to extricate itself and fly away.

In no instance have I known of the Shrike attacking so large a bird as the Sparrow Hawk, much less one so well able to defend itself. Whether or not the Hawk had become entangled in the hedge before the attack of the Shrike is not known, but that the Hawk was impaled on the thorns and that the Shrike was striking it with wings and beak is certain.

Material for the Study of the Variation of Etheostoma caprodes Rafinesque and Etheostoma nigrum Rafinesque in Turkey Lake and Tippecanoe Lake.* By W. J. Moenkhaus.

The matter contained in the present paper relates to two species of darters, *Etheostoma caprodes* and *Etheostoma nigrum* from Turkey Lake and Tippecanoe Lake.† The discussion is confined almost wholly to the variation in the dorsal and anal fins. In a few instances the scales in the lateral line and on the nape are also considered. The aim of this paper is to answer the following questions:

1. Do the sexes present any differences in their variations?
2. How do the specimens in Tippecanoe Lake differ from those of Turkey Lake?
3. Is the variation in the two species determinate with the locality; *i. e.*, do both vary in the same direction in the same locality?
4. Do the broods of one season differ from the broods of another season?
5. Are the variations of one fin correlated with the variations in the others?

I. DO THE SEXES PRESENT ANY DIFFERENCES IN THEIR VARIATIONS?

Inasmuch as all the specimens upon which the comparisons are to be made include the two sexes, it will be advisable to first determine just what modifications sex has upon the different structures. The specimens of *Etheostoma caprodes*

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*Contributions from the Zoological Laboratory of the Indiana University under the direction of C. H. Eigenmann, No. 22.

†For the purpose of making a detailed comparison between the faunas of two units of environment, a Biological Station has been established on Turkey Lake, Kosciusko County, Indiana. Five miles from this lake is another lake of different shape and depth—Tippecanoe Lake. The two lakes are on opposite sides of the watershed separating the St. Lawrence from the Mississippi Basin. A physical survey has been made of these lakes, and as far as our means permit, the physical and biological conditions of the two lakes are being studied as two units of environment within which we wish to determine the extent of variation in the non-migratory vertebrates, the kind of variation, whether continuous or discontinuous, the quantitative variation, the direction of variation, and the annual or periodic variation and the effect of selection. The present is one of a series of papers illustrating these points. C. H. E.

and *Etheostoma nigrum* from the lakes show no external marks by which the sexes can be separated. By examining the glands, however, the sexes can readily be distinguished even in individuals only 25 mm. long (about two months old in case of *E. caprodes*).

Below are given a series of tables which contain the counts of the fins for much of the material to be described in the following pages. In all the tables the counts are given for the sexes separately in the first two columns and for the sexes combined in the third column. The first item is the number of specimens examined of each brood. The details of the spinous dorsal, soft dorsal and anal fin follow in the order given. Where it has been possible the broods and ages have also been given separately, so that it is possible to compare not only the sexes with each other, but also the same sex in the two lakes in the different broods and ages and in the two species.

It needs but a glance through these tables to show that the two sexes do not differ materially from each other, and that for all purposes of comparisons that are to be made in this paper the sex may be dropped out of consideration. It seems advisable, however, to consider in brief the details of some of the tables.

In Table I are given the counts for 1,275 specimens of *Etheostoma caprodes* from Tippecanoe Lake. These fall into two broods—that of 1896, 500 in number, taken the same summer (marked '96^{6}), and that of 1895, 500, taken the same summer (marked '95^{5}), and the remaining 275 the following summer ('95^{6}). In the first three columns is given the brood of '95^{5}, and in the second three columns the brood of '95 after the individuals had attained an age of one year. In the third column is given the brood of '96^{6}.

Without considering the differences that may exist between the different broods or between the different ages of the same brood, we may notice some things about the two sexes within the same brood or age.

1. In all of the structures the percentages are strikingly similar for any given number of rays or spines.

2. The nature of the variation in both sexes is the same. When this is symmetrical in one sex, we find the same symmetry in the other sex and *vice versa*. This similarity in symmetrical variation in the two sexes is well illustrated in the anal fin of the broods of '96^{6}. Here the pervailing number of rays is 11, 57.20% having this number in the males and 60.80% in the females. In the males, 20% have 10 and 22% have 12. To correspond to this in the females, 19.20% have 10 and 19.60% have 12. The dorsal rays in the broods of '95^{5} show asymmetrical variation very well. Here the prevailing number of rays is 16, 50% having this number in the males and 48.40% in the females. In the males, 39.60% have the

next lower number, 15, while only 4.80% have the next higher number, 17. Similarly, in the females, 42% have 15 and only 5.60% have 17. While therefore the per cent. of specimens possessing a given number of rays may differ slightly in the two sexes, this slight dissimilarity is lost to a very large extent in the much more striking correspondence of the nature of the variation of the two sexes.

3. The males are more variable than the females. Recently the method of using the average deviation of each specimen from the mean as an index of variability, has come into vogue. While this method tells really nothing of the extent of variation from the mean, the symmetry or asymmetry of variation or of instances of great variability, it is of interest in permitting a comparison between two groups of individuals to be expressed numerically, a method more striking to a hasty glance than the parallel columns of the tables. Compared in this way, it is found in Table I that the males have usually a greater index of variability than the females, the only exception in Table I being in the specimens '95[5]. Arranging these indices of variability, we find the variability of the males and females to be to each other as 5073:4680. The means were here calculated to two decimals only, so that a slight error is usually present in the index of variability of the males and females combined, as given in the third series of columns, and the indices of variability of the males and females separately. Averaging the per cents. of specimens having the highest prevailing number in the fins, we find that on an average 1.1 per cent. more females have the prevailing number than males.

TABLE I.

ETHEOSTOMA CAPRODES FROM TIPPECANOE LAKE.

	Brood of 1895 taken in 1895. '95[5].			Brood of 1895 taken in 1896. '96[6].			Brood of 1896 taken in 1896. '96[6].		
	♂	♀	♂ and ♀	♂	♀	♂ and ♀	♂	♀	♂ and ♀
Number of specimens examined	250	250	500	150	125	275	250	250	500
A.—Dorsal Spines									
Per cent. of specimens having 10 dorsal spines	....	....	....	....	....	....	....	.40	.20
Per cent. of specimens having 11 dorsal spines	....	....	....	....	....	....	....	.40	.20
Per cent. of specimens having 12 dorsal spines	1.2	1.6	1.4	....	.8	.36	.40	.80	.60
Per cent. of specimens having 13 dorsal spines	12.4	16.4	14.4	18.66	15.20	17.06	6.40	6.40	6.40
Per cent. of specimens having 14 dorsal spines	64.	60.4	62.2	54.66	56.00	55.18	61.20	64.40	62.80
Per cent. of specimens having 15 dorsal spines	21.6	20.4	21.0	21.35	26.40	23.59	30.40	27.20	28.80
Per cent. of specimens having 16 dorsal spines	.4	.8	.6	5.33	1.60	3.64	1.20	.40	.80
Per cent. of specimens having 17 dorsal spines	.4	.4	.4	....	....	....	.40	....	.20
Mean number of dorsal spines	14.08	14.03	14.06	....	....	14.05	14.27	14.17	14.22
Average variation $\frac{\Sigma 1}{n}$	.4381	.4450	.4396	....	....	....	.5091	.4650	.4888

B.—Dorsal Rays—									
Per cent. of specimens having 10 dorsal spines	....	....	....	....	....	....	.40	....	.20
Per cent. of specimens having 11 dorsal spines	....	....	....	....	....	....	....	....	....
Per cent. of specimens having 12 dorsal spines	....	.40	.20	....	....	....	....	....	....
Per cent. of specimens having 13 dorsal spines	....	....	....	....	....	....	....	....	....
Per cent. of specimens having 14 dorsal spines	4.80	3.20	4.00	5.33	6.40	5.81	2.40	.80	1.60
Per cent. of specimens having 15 dorsal spines	39.60	42.00	40.80	50.00	46.40	48.28	27.20	22.40	24.80
Per cent. of specimens having 16 dorsal spines	50.00	48.40	49.20	41.33	42.40	41.74	52.40	58.00	55.20
Per cent. of specimens having 17 dorsal spines	4.80	5.60	5.20	3.33	4.80	3.99	16.00	17.60	16.80
Per cent. of specimens having 18 dorsal spines	.40	.40	.40	....	....	....	1.60	1.20	1.40
Per cent. of specimens having 19 dorsal spines	....	....	....	....	....	....	....	....	....
Per cent. of specimens having 20 dorsal spines	.40	....	.20	....	....	....	....	....	....
Mean number of dorsal rays	15.58	15.56	15.57	....	....	15.44	15.85	15.96	15.90
Average variation	.6110	.6027	.6069	....	....	....	.5960	.4614	.5348
C. Anal.									
a. Spines—									
Per cent. of specimens having 1 spine	....	....	....	....	2.00	5.60	3.63	....	....
Per cent. of specimens having 2 spines	....	....	....	....	98.00	94.40	96.37	....	....
b. Rays—									
Per cent. of specimens having 9 rays	.40	.40	.40	2.66	2.40	2.54	....	....	....
Per cent. of specimens having 10 rays	21.20	23.60	22.40	27.97	29.60	28.68	20.00	19.20	19.60
Per cent. of specimens having 11 rays	58.00	58.00	58.00	51.28	59.20	54.81	57.20	60.80	59.00
Per cent. of specimens having 12 rays	19.60	17.20	18.40	17.98	8.80	13.29	22.00	19.60	20.80
Per cent. of specimens having 13 rays	.80	.80	.80	....	....	....	.80	.40	.60
Mean number of anal rays	10.99	10.94	10.96	....	....	10.80	11.04	11.01	11.025
Average variation	.4375	.4287	.4325	....	....	....	.4577	.4020	.4293

TABLE II.

ETHEOSTOMA CAPRODES FROM TURKEY LAKE.

	Brood '93⁵.			Brood '94⁵.			Brood '95⁵.		
	Male.	Female.	Male and Female.	Male.	Female.	Male and Female.	Male.	Female.	Male and Female.
Number of specimens	107	117	224	144	81	225	72	43	115
A.—Dorsal spines.									
Per cent. of specimens having 12 dorsal spines	....	....	....	1.36	....	0.88	....	....	....
Per cent. of specimens having 13 dorsal spines	4.67	4.23	4.44	9.52	7.40	8.76	2.78	....	1.74
Per cent. of specimens having 14 dorsal spines	34.58	38.13	37.85	47.60	53.06	49.49	43.03	30.24	38.26
Per cent. of specimens having 15 dorsal spines	50.46	51.70	51.06	34.68	34.55	34.60	47.19	55.80	50.43
Per cent. of specimens having 16 dorsal spines	9.35	5.93	7.55	6.80	3.70	5.69	6.94	9.30	7.83
Per cent. of specimens having 17 dorsal spines	0.93	....	0.44	0.68	1.23	0.44	....	4.65	1.74
Mean number of dorsal spines	....	....	14.70	....	....	14.68	....	....	14.69

B.—Dorsal rays.									
Per cent. of specimens having 12 dorsal rays	....	....	....	0.68	....	0.44	1.39	....	0.87
Per cent. of specimens having 13 dorsal rays	....	1.69	0.89	2.04	4.94	3.07	2.78	....	1.74
Per cent. of specimens having 14 dorsal rays	27.08	18.63	22.64	31.96	27.14	30.22	44.42	37.20	41.74
Per cent. of specimens having 15 dorsal rays	57.91	58.44	58.16	55.08	45.65	51.68	49.97	53.48	51.30
Per cent. of specimens having 16 dorsal rays	14.98	16.94	15.98	8.84	22.20	13.58	1.39	9.30	4.35
Per cent. of specimens having 17 dorsal rays	....	3.38	1.77	1.36	....	0.88	....	....	....
Per cent. of specimens having 18 dorsal rays	....	0.85	0.44	....	....	....	....	....	....
Mean number of dorsal rays	....	....	14.95	....	....	14.97	....	....	14.57
C.—Anal rays.									
Per cent. of specimens having 7 anal rays	....	....	....	....	....	....	1.39	....	0.87
Per cent. of specimens having 8 anal rays	....	....	....	0.68	....	0.44	....	....	....
Per cent. of specimens having 9 anal rays	....	0.85	0.44	2.72	....	1.75	4.16	6.98	5.22
Per cent. of specimens having 10 anal rays	23.35	21.17	22.20	27.88	39.49	31 97	38.86	32.55	36.53
Per cent. of specimens having 11 anal rays	58.84	55.90	57.28	51.68	51.83	57.73	49.97	53.48	51.30
Per cent. of specimens having 12 anal rays	17.75	20.33	19.09	16.32	8.64	13.58	4.16	6.98	5.22
Per cent. of specimens having 13 anal rays	....	1.69	0.89	....	....	....	1.39	....	0.87
Mean number of anal rays	....	....	11.02	....	....	10.86	....	....	10.56

Table II contains the counts for 564 specimens of *Etheostoma caprodes* from Turkey Lake. These fall into three different broods, those of '93[5], '94[5] and '95[5], all three broods having been taken during the summer of '95, so that they also represent three different ages. The same can be said of the specimens in this table that was said about the specimens in Table I. The number of specimens in each case here is much smaller than in the other table, and, as a consequence, the per cents in the two sexes do not agree quite so perfectly.

TABLE III.

ETHEOSTOMA NIGRUM FROM TIPPECANOE LAKE.

	♂	♀	♂ and ♀
Number of specimens	250	250	500
A.—Dorsal spines.			
Per cent. of specimens having 7 dorsal spines	1.20	2.40	1.80
Per cent. of specimens having 8 dorsal spines	15.60	15.20	15.40
Per cent. of specimens having 9 dorsal spines	62.80	56.80	59.80
Per cent. of specimens having 10 dorsal spines	19.20	24.80	22.00
Per cent. of specimens having 11 dorsal spines	1.20	0.80	1.00
Average number of dorsal spines	9.03	9.06	9.04
Average variation	.23016	.26288	....
B.—Dorsal rays.			
Per cent. of specimens having 11 dorsal rays	2.00	2.00	2.00
Per cent. of specimens having 12 dorsal rays	35.60	40.80	38.30
Per cent. of specimens having 13 dorsal rays	55.20	48.00	51.60
Per cent. of specimens having 14 dorsal rays	7.20	8.80	8.00
Per cent. of specimens having 15 dorsal rays	....	0.40	0.20
Average number of dorsal rays	12.71	12.64	12.67
Average variation	.53992	.59584	....
C.—Anal rays.			
Per cent. of specimens having 7 anal rays	0.40	0.80	0.60
Per cent. of specimens having 8 anal rays	8.80	13.60	11.20
Per cent. of specimens having 9 anal rays	66.40	56.80	61.60
Per cent. of specimens having 10 anal rays	22.80	28.40	25.60
Per cent. of specimens having 11 anal rays	1.60	0.40	1.00
Average number of anal rays	9.16	9.15	9.15
Average variation	.43792	.50336	....

Table III contains the counts for 500 specimens of *Etheostoma nigrum* from Tippecanoe Lake. The females of this group of individuals are more variable than the males in all structures. This difference in variability is most pronounced in the anal fin. In the males 66.40 per cent. of the specimens have the prevailing number of rays, 9, as compared to 56.80 per cent. in the females. This leaves 33.60 per cent. of the specimens varying from this number in the males compared to 43.20 per cent. in the females. This difference is less pronounced in the other two fins, but from its constancy in all three of the fins it certainly must be taken as a sexual difference.

The average variability of each individual from the mean of the group is given under each column. Averaging these averages we have the average deviation of the male to the female as .40266 : .4540.

II. HOW DO THE SPECIMENS IN TIPPECANOE LAKE DIFFER FROM THOSE IN TURKEY LAKE?

In a previous article* I described a number of local varieties of color patterns that were found in this species. Later I gave a more detailed comparison of this species as it occurs in Turkey Lake and Tippecanoe Lake. The number of specimens involved were 600 from Turkey Lake and 300 from TipPecanle Lake. Comparisons were made upon the dorsal and anal fins, the scale in the lateral line and on the nape and upon the color pattern. The following facts were observed:

1. *Coloration.*—The color-pattern of Turkey Lake specimens is, on the whole, of a more blotched character than that of Tippecanoe Lake specimens, and shows a slighter affinity to the simple, primitive coloration characteristic of the Wabash River forms.

2. *Lateral Line.*—The specimens of Turkey Lake have on an average two more scales in the lateral line. The average number for Turkey Lake is 89.46 for the left side, 89.74 for the right side; for Tippecanoe Lake, 87.69 for the left side, 87.45 for the right side.

3. *Squamation of Nape.*—In Turkey Lake the nape is usually naked; in Tippecanoe Lake the nape is usually scaled. (See Table V.)

4. *Do sal and Anal Fin.*—Decided differences are found in the dorsal fins. The data have been incorporated in the tables below, and these differences will be given then. The anal fin is slightly larger in the Tippecanoe Lake specimens.

*The variation of *Etheostoma caprodes* Rafinesque in Turkey Lake and Tippecanoe Lake Proc. Ind. Acad. Sci. No. V, 1895, pp. 278-296.

I have since examined the fins of 250 more specimens of *Etheostoma caprodes* from Turkey Lake and 1,175 more specimens from Tippecanoe Lake. The data for these are combined with those previously described and given in the tables below. In addition, the nape and fins of 500 specimens of *Etheostoma nigrum* from Tippecanoe Lake and 100 specimens from Turkey Lake have been examined. The sex has been determined in most of this material, so that a comparison of the proportion of the sexes in the two lakes can be made.

a. ETHEOSTOMA CAPRODES.

1. Proportion of Sexes.—The proportion of the sexes in the two lakes will be found in Table IV. In all the broods, excepting the broods of '93^5, of both lakes, the males are in the majority. In Turkey Lake this majority is greater than in Tippecanoe Lake. In the latter the mean per cent. of males is 55.44 and the females 44.56. In Turkey Lake the mean per cent. of males is 63.96 and of females 36.04. The broods of '93^5 are not included in the latter because this group contains many females of preceding broods that have survived the males or outdone them in growth. Thus all of the larger specimens of this group are females. One can be quite sure when he meets an exceptionally large and aged-looking specimen that it is a female. The broods of '93^5, determined solely by the size of the specimens, ought therefore to show an abnormal per cent. of females and should not be taken to determine the true proportion of the sexes.

TABLE IV.

Number of Specimens.	Tippecanoe Lake.		Turkey Lake.	
	Male.	Female.	Male.	Female.
882 specimens, brood '96^6	58.48	41.52	......	....
543 specimens, brood '95^5	52.48	47.52	......	....
280 specimens, brood '95^6	55.35	44.65	......	....
115 specimens, brood '95^5	......	....	62.60	37.40
222 specimens, brood '94^5	......	....	65.32	34.68
228 specimens, brood '93^5	......	....	45.62	54.38

2. Squamation of Nape.—Table V represents the data for the squamation of the nape of 600 specimens from Turkey Lake and 300 specimens from Tippecanoe Lake. Eighty-eight per cent. have the nape naked in Turkey Lake and only 19 per cent. from Tippecanoe Lake. Twenty-eight per cent. from the latter lake have scales over the entire nape.

TABLE V.

	From Turkey Lake.	From Tippecanoe Lake.
Per cent. of specimens having no scales on nape..	88.00	19.32
Per cent. of specimens having few scales on nape...	8.00	23.87
Per cent. of specimens having several scales on nape	4.00	28.32
Per cent. of specimens having nape thinly scaled...	0.20	16.67
Per cent. of specimens having nape closely scaled..	....	11.74

In Tables VI, VII and VIII are given the counts for the anal, spinous dorsal and soft dorsal fins, respectively. The per cents. are based on 1,475 specimens of all ages from Tippecanoe Lake and 850 of all ages from Turkey Lake.

C. Anal Rays.—From Table VI, it will be seen that the anal fin is somewhat larger in Tippecanoe Lake than in Turkey Lake. This is shown by the decrease in the per cent. of specimens having the prevailing number, 11, and the increase in the per cent. of specimens having the next lower number, 10, in the Turkey Lake specimens. The mean number of rays is 10.76 for Turkey Lake and 10.97 for Tippecanoe Lake.

TABLE VI.

	Tippecanoe Lake.	Turkey Lake.
Per cent. of specimens having 7 anal rays... ...	....	0.12
Per cent. of specimens having 8 anal rays.......	....	0.23
Per cent. of specimens having 9 anal rays.......	0.75	1.76
Per cent. of specimens having 10 anal rays.......	21.92	31.87
Per cent. of specimens having 11 anal rays.......	58.23	53.40
Per cent. of specimens having 12 anal rays.......	19.66	12.23
Per cent of specimens having 13 anal rays.......	0.48	0.35
Mean number of rays	10.97	10.76

3. Dorsal Spines.—The dorsal spines in the Tippecanoe Lake specimens vary from 10 to 17. The prevailing number is 14, 61.44 per cent. having this number. The variation is slightly greater toward a higher number than toward a lower number of spines. In Turkey Lake specimens the spines vary from 12 to 18. The prevailing numbers are 14 and 15, 42.57 per cent. and 43.48 per cent. respectively having this number. From these the variation is symmetrical in both directions. The mean is 14.20 for Tippecanoe Lake and 14.56 for Turkey Lake.

TABLE VII.

	Tippecanoe Lake.	Turkey Lake.
Per cent. of specimens having 10 dorsal spines...	.069	....
Per cent. of specimens having 11 dorsal spines...	.069	....
Per cent. of specimens having 12 dorsal spines...	0.82	0.23
Per cent. of specimens having 13 dorsal spines...	11.85	5.17
Per cent. of specimens having 14 dorsal spines...	61.44	42.57
Per cent. of specimens having 15 dorsal spines...	25.21	43.48
Per cent. of specimens having 16 dorsal spines...	1.30	7.29
Per cent. of specimens having 17 dorsal spines...	0.27	0.94
Per cent. of specimens having 18 dorsal spines...	....	0.23
Mean number of rays.....................	14.20	14.56

4. Dorsal Rays.—The dorsal rays vary from 10 to 20 in Tippecanoe Lake. The prevailing number of rays is 16, 51.03 per cent. having this number. There is a tendency to vary toward a lower number of rays. Thus, 35.55 per cent. have 15 and only 10.74 per cent. have 17. In Turkey Lake the soft dorsal varies from 12 to 18 rays. The prevailing number here is 15, with 53.98 per cent. of the specimens having this number. Here, too, the tendency to vary toward a lower number is quite marked, 31.40 per cent. having 14 and only 11.17 per cent. having 16. The mean number of rays is 15.66 for Tippecanoe Lake and 14.80 for Turkey Lake.

TABLE VIII.

	Tippecanoe Lake.	Turkey Lake.
Per cent. of specimens having 10 dorsal rays.....	0.07	....
Per cent. of specimens having 11 dorsal rays.....	....	....
Per cent. of specimens having 12 dorsal rays.....	0.07	0.23
Per cent. of specimens having 13 dorsal rays.....	....	1.88
Per cent. of specimens having 14 dorsal rays.....	3.49	31.40
Per cent. of specimens having 15 dorsal rays.....	35.55	53.98
Per cent. of specimens having 16 dorsal rays.....	51.03	11.17
Per cent. of specimens having 17 dorsal rays.....	10.74	1.29
Per cent. of specimens having 18 dorsal rays.....	0.69	0.23
Per cent. of specimens having 19 dorsal rays.....	....	....
Per cent. of specimens having 20 dorsal rays.....	0.07	....
Mean number of rays.....................	15.66	14.8

b. ETHEOSTOMA NIGRUM.

1. Squamation of Nape.—The following Table IX, is based on 100 specimens from each of the lakes, and is intended to show the occurrence of scales on the nape in this species. Eighty-five per cent. of the specimens from Turkey Lake have their nape naked, and none have their nape completely scaled. Compared with this, only 50 per cent. of the specimens from Tippecanoe Lake have a naked nape, while four per cent. have their nape completely scaled.

TABLE IX.

	Turkey Lake.	Tippecanoe Lake.
Per cent. of specimens having no scales on nape..	85.00	50.00
Per cent. of specimens having few scales on nape.	13.00	28.00
Per cent. of specimens having several scales on nape	2.00	18.00
Per cent. of specimens having nape thinly scaled .	....	2.00
Per cent. of specimens having nape closely scaled.	....	2.00

In Tables X, XI, and XII are given the counts of the anal rays, dorsal spines and dorsal rays of *Etheostoma nigrum* from the two lakes. The counts are based on 100 specimens from Turkey Lake and 500 from Tippecanoe Lake.

2. Anal Rays.—Table X. The anal rays vary from 7 to 11 in Tippecanoe Lake, 61.60 per cent. having nine rays. There is a tendency to vary toward an increased number of rays, 25.60 per cent. having 10, and but 11.20 per cent. eight. In Turkey Lake the variation is from eight to ten; 58 per cent. have nine, 40 per cent. have a smaller number of rays and only two per cent. a greater number. The mean number of anal rays is 9.15 for Tippecanoe Lake and 8.62 for Turkey Lake.

TABLE X.

	Tippecanoe Lake.	Turkey Lake.
Per cent. of specimens having 6 anal rays	....	....
Per cent. of specimens having 7 anal rays	0.60	....
Per cent. of specimens having 8 anal rays	11.20	40.00
Per cent. of specimens having 9 anal rays	61.60	58.00
Per cent. of specimens having 10 anal rays	25.60	2.00
Per cent. of specimens having 11 anal rays	1.00	....
Mean number of rays	9.15	8.62

3. Dorsal Spines.—Table XI. The dorsal spines vary from 7 to 11 in Tippecanoe Lake, 59.80 per cent. having nine. The variation from this number is almost symmetrical. In Turkey Lake the variation ranges from 7 to 10. Nine is the prevailing number, 52 per cent. having this number. The variation toward a lower number of spines is much the greater, 39 per cent. having eight, compared to five per cent. having ten. The mean for Tippecanoe Lake is 9.04, and 8.58 for Turkey Lake.

TABLE XI.

	Tippecanoe Lake.	Turkey Lake.
Per cent. of specimens having 6 dorsal spines...	....	....
Per cent. of specimens having 7 dorsal spines...	1.80	4.00
Per cent. of specimens having 8 dorsal spines...	15.40	39.00
Per cent. of specimens having 9 dorsal spines...	59.80	52.00
Per cent. of specimens having 10 dorsal spines...	22.00	5.00
Per cent. of specimens having 11 dorsal spines...	1.00	....
Mean number of rays.....................	9.04	8.58

4. Dorsal Rays.—The Tippecanoe Lake specimens present a range of variation from 11 dorsal rays to 15. The prevailing number is 13, 51.60 per cent. possessing this number, while 38.20 per cent. have 12 and only 8 per cent. have 14. The Turkey Lake specimens vary from 11 to 13. The prevailing number here is 12, 59 per cent. having this number. The variation toward a higher number is greater than toward a lower number. Thus, 36 per cent. have 13 and only 50 per cent. have 11. The mean number of rays is 12.67 for Tippecanoe Lake and 12.31 for Turkey Lake.

TABLE XII.

	Tippecanoe Lake.	Turkey Lake.
Per cent. of specimens having 11 dorsal rays.....	2.00	5.00
Per cent. of specimens having 12 dorsal rays.....	38.20	59.00
Per cent. of specimens having 13 dorsal rays.....	51.60	36.00
Per cent. of specimens having 14 dorsal rays.....	8.00	....
Per cent. of specimens having 15 dorsal rays.....	0.20	....
Mean number of rays.....................	12.67	12.31

From the foregoing comparison it will be seen that the specimens of Tippecanoe Lake differ in every structure examined from those of Turkey Lake. This is true for both species. In some structures this difference is small, as in the anal fin, and in others it is greater, as in the scales on the nape and the dorsal rays.

III. IS THE VARIATION IN THE TWO SPECIES DETERMINATE WITH THE LOCALITY?

But of greater importance is the fact that both species are being modified in the same way by the same lake. Thus, with one exception, if a given structure varies in a certain manner in *Etheostoma caprodes* in Tippecanoe Lake, the same structure will show a similar modification in *Etheostoma nigrum* in the same lake. This holds true with one exception.

From tables V and IX, it is seen that both species show a greater per cent. of individuals with a scaled nape in Tippecanoe Lake than in Turkey Lake. For Tippecanoe Lake the percents of specimens with a naked nape are 19.32, and 50 for *Etheostoma caprodes* and *Etheostoma nigrum* respectively, while for Turkey Lake they are 88 and 85 respectively.

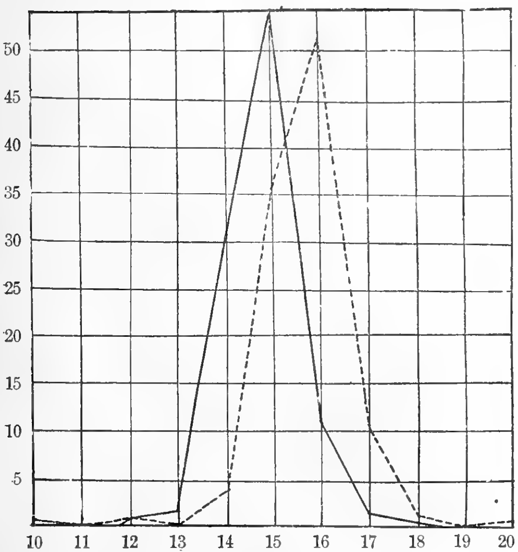


Fig. 1.

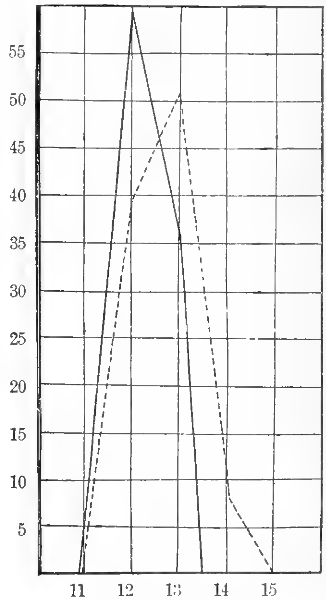


Fig. 2.

In Tippecanoe Lake the anal fin in both species is slightly larger. The *nature* of the variation in the anal fin is quite definite for each lake. Thus from Tables VI and X we find that the variation in Tippecanoe Lake is very nearly symmetrical around the prevailing number, 9, while in Turkey Lake the variation is pronouncedly asymmetrical, a much greater per cent. varying below nine than above.

On the contrary, the dorsal spines of one species show an increase, and of the other a decrease in number. Aside from this exception, however, there is, as in the anal fin, a marked parallelism in the *nature* of the variation in the two species for each lake. Thus in Tippecanoe Lake the variation is nearly symmetrical, while in Turkey Lake it is very asymmetrical. The asymmetry in *Etheostoma caprodes* is due to the difference in the three broods included, yet, as can be seen from Fig. 2, each brood shows this asymmetrical variation in its dorsal spines.

The soft dorsal in both species has one more ray in Tippecanoe Lake than in Turkey Lake. In Figs. 1 and 2 are given the curves for the dorsal rays. In the curves for both species the continuous line is for the Turkey Lake specimens and the broken line for Tippecanoe Lake specimens. From these it will be seen that in Tippecanoe Lake the prevailing number is 16 and 13 for *Etheostoma caprodes* and *Etheostoma nigrum* respectively, and in Turkey Lake it is 15 and 12 respectively. In the dorsal rays, too, the Turkey Lake specimens, in contrast to the Tippecanoe Lake specimens, vary asymmetrically.

The comparison of the two lakes, in so far as these two species are concerned, may be briefly summarized as follows: Tippecanoe Lake is characterized by a greater number of scales on the nape and rays in the anal and soft dorsal. The variations are very nearly symmetrical in Tippecanoe Lake, while in Turkey Lake they are decidedly asymmetrical. The proportion of males to females is greater in Tippecanoe Lake than in Turkey Lake.

This parallelism in the variation of these two species becomes the more interesting when considered in another relation, namely, that one of the species does not thrive equally well in both lakes. *Etheostoma nigrum* is as excessively rare in Turkey Lake as it is abundant in Tippecanoe Lake. One to 50 approximates the ratio. On the other hand, *Etheostoma caprodes* is equally abundant in both lakes. The modifications found in these structures, therefore, can not be attributed to any selective influence, or at best, this influence is so slight as to be largely overcome in its effect by ontogenic influences. Otherwise we could hardly account for the parallel modifications in two nearly related species living side by side, the one thriving, and the other on the point of extermination.

IV. DO THE BROODS OF ONE SEASON DIFFER FROM THE BROODS OF ANOTHER SEASON?

The different broods could be clearly separated only in *Etheostoma caprodes.* A series of 565 specimens from Turkey Lake taken during the summer of '95 were readily separable into three groups on the basis of their size. These three groups represented the broods of '93, '94 and '95. These are the broods contained in Table 1. The comparison of the broods has already been made (Proc. Ind. Acad. Sci. No. 5, pp. 289–96, 1895), but the following points seem worth repeating in this connection.

1. The broods of '93[5] and '95[5] were alike in all the structures examined.

2. The brood of '94[5] differed from the other two broods in having on an average two more scales in the lateral line, and a fewer number of dorsal spines.

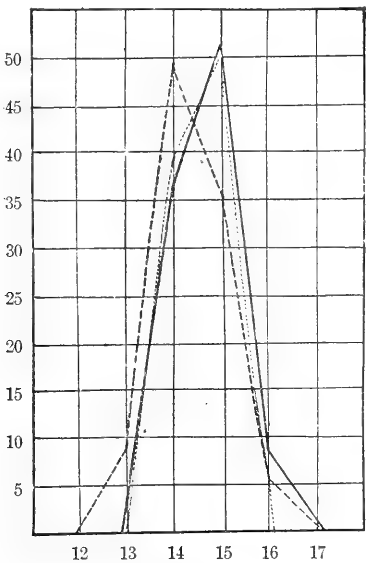


FIG. 3.

In Fig. 3 are given the curves for the dorsal spines of these three broods. The curves are based on the counts for the dorsal spines given in Table I. The continuous line is for the broods of '93[5], the broken line for the broods of '94[5] and the dotted line for the broods of '95[5].

From these it will be noticed that the curves for the broods of '93 and '95 are almost identical, with 15 as the prevailing number of spines, while the brood of '94 stands quite distinct, with 14 as the prevailing number. The mean for the broods of '93 and '95 is 14.65 and 14.69 respectively, and for the brood of '94, 14.39.

A comparison of the fins of 500 specimens, including an equal number of each sex, from Tippecanoe Lake, of the brood of '95, taken the same summer with 500 specimens of both sexes of the brood of '96 taken the same summer, shows them to be almost identical in the anal rays and dorsal spines, as can be seen from the counts given in Table II. Thus, in the anal fin we have 10.96 and 11.02 for the mean in the two broods; 58 and 59 are the percents of specimens having the prevailing number, 11 rays. Around this the variation is symmetrical in both broods, The means for the dorsal spines are 14.06 and 14.22. The per cent. of specimens having the prevailing number, 14, are 62.20 and 62.80. The variation from this number is nearly the same.

These two broods, however, show quite a difference in the dorsal rays, as shown by the mean and by the nature of the variation. The mean number of rays for the brood of '95 is 15.57 and 15.90 for the brood of '96. In Fig. 4 are given the curves for the dorsal rays and Table XIII contains the details of the counts. In the curves the continuous lines represent the brood of '95.

Both broods have 16 as their prevailing number, 49.20 per cent. in the brood of '95 and 55.20 per cent. in the brood of '96 having this number. In the brood of '96 there is an approximation to a symmetrical variation around this number, while in the brood of '95 the number of specimens, 40.80 per cent. having the next lower number, 15, is almost as great as that of 16.

TABLE XIII.

	'95[5].	'96[6].
Per cent. of specimens having 10 dorsal rays	....	0.20
Per cent. of specimens having 11 dorsal rays	....	....
Per cent. of specimens having 12 dorsal rays	0.20	....
Per cent. of specimens having 13 dorsal rays	....	....
Per cent. of specimens having 14 dorsal rays	4.00	1.60
Per cent. of specimens having 15 dorsal rays	40.80	24.80
Per cent. of specimens having 16 dorsal rays	49.20	55.20
Per cent. of specimens having 17 dorsal rays	5.20	16.80
Per cent. of specimens having 18 dorsal rays	0.40	1.40
Per cent. of specimens having 19 dorsal rays	....	....
Per cent. of specimens having 20 dorsal rays	0.20	....

Thus the broods of '94[5] in Turkey Lake differs from the broods of the preceding and succeeding year in the number of scales in the lateral line and in the number of dorsal spines, and the broods of '95[5] in Tippecanoe Lake differ from the broods of '96[6] in the number of dorsal rays. In regard to the former, I have already remarked that "the difference in the dorsal spines may possibly be due to the presence of local races in the lake. While this may possibly be the case, it is not at all probable, because, in the first place, the curve constructed for the dorsal spines of 100 specimens of the brood of '93[5] taken within a distance of 100

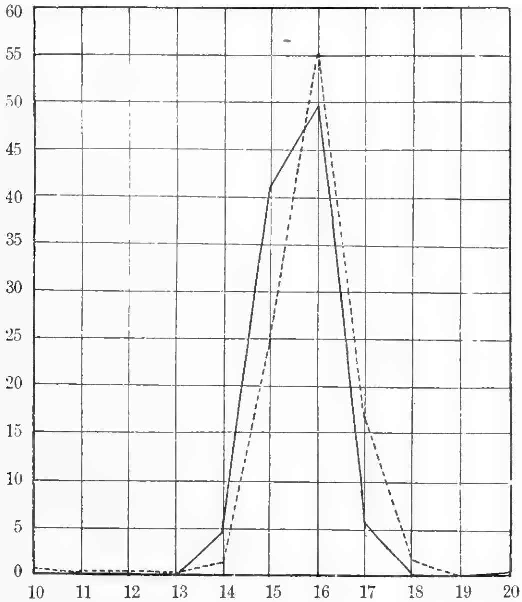


Fig. 4.

yards along the shores where the conditions were undoubtedly uniform, gave a curve identical with that for all the broods of '93[5]. In the second place, the '93[5] and '94[5] specimens are found in about equal abundance together, and since these were promiscuously preserved it is altogether probable that from any given locality, an equal number of each brood was taken."

I have since examined a considerable number of specimens from three distant localities in the lake, and find that they do not present sufficient local differences to account for these occurring in the different broods.

In regard to the broods in Tippecanoe Lake it need but be said that they were of the same age and were collected from the same place in the lakes.

The only remaining element, it seems, with which to correlate these differences is the season in which the broods were hatched. The characters of broods vary with the varying conditions of the years. Equally great changes are perhaps not uncommonly produced artificially in the laboratory by subjecting organisms to changed conditions during their ontogeny, so that there is nothing unusual in the changes occurring in these broods. But it is interesting to know that in *nature* within areas of such comparative uniformity as one of these small lakes the most uniform environment from year to year possible in this latitude there is a sufficient fluctuation in the seasonal conditions to produce these measurable differences found in these different broods.

V. ARE THE VARIATIONS IN ONE FIN CORRELATED WITH THE VARIATIONS IN THE OTHERS?

Most of the specimens from both lakes were separated into different groups on the basis (1) of the number of rays in the anal fin, and (2) of the number of spines in the dorsal fin. In the former grouping, by finding the average number of elements in the dorsal fins, both separately and combined, for each group, the correlation of the variations in the anal fin with that of the dorsal separate and combined, can be determined. Similarly in the latter grouping (2) the correlation between the two dorsals can be determined.

In the way of an illustration, the data for the broods of '95[5] and '96[6] from Tippecanoe Lake are given in Table XV. The number of specimens in each group occurs in the first column.

It will be observed that in both broods there is a definite correlation between the anal fin and dorsal fins, separately and combined.

When the anal rays increase in number, the dorsal spines, dorsal rays, or both combined, also increase. There are several exceptions to this law, noteworthy in the dorsal spines of the twelve anal-rayed group and the dorsal rays in the eleven anal-rayed group of the brood of '96[6].

In all cases the increase in the dorsal is considerably smaller than the increase in the anal. The correlation is stronger for the two dorsals combined than for them separately, and of the latter, it is the stronger for the dorsal rays. The ratio of increase in the dorsal to the increase in the anal is approximately twelve to two, five to two and four to two in the spinous dorsal, soft dorsal and both combined, respectively.

Table XIV.

ETHEOSTOMA CAPRODES.

	'95[5]				'96[6]			
	Number of Specimens.	Average Number of Dorsal Spines.	Average Number of Dorsal Rays.	Average Number of Dorsal Spines and Dorsal Rays.	Number of Specimens.	Average Number of Dorsal Spines.	Average Number of Dorsal Rays.	Average Number of Dorsal Spines and Rays.
Specimens with 9 anal rays	2	13.50	15.00	28.50	90	......	......	......
Specimens with 10 anal rays	113	13.85	15.31	28.68	98	14.12	15.60	29.82
Specimens with 11 anal rays	298	14.11	15.59	29.34	294	14.24	15.49	30.14
Specimens with 12 anal rays	94	14.15	15.86	30.01	105	14.20	15.90	30.46
Specimens with 13 anal rays	4	14.00	16.50	30.50	3	14.75	16.75	31.33
Specimens with 10 dorsal spines	......	......	......	......	1	......	16.00	......
Specimens with 11 dorsal spines	......	......	......	......	1	......	17.00	......
Specimens with 12 dorsal spines	4	......	15.50	......	3	......	16.33	......
Specimens with 13 dorsal spines	73	......	15.63	......	31	......	16.03	......
Specimens with 14 dorsal spines	319	......	15.58	......	316	......	15.91	......
Specimens with 15 dorsal spines	105	......	15.51	......	142	......	15.84	......
Specimens with 16 dorsal spines	3	......	15.33	......	5	......	16.20	......
Specimens with 17 dorsal spines	1	......	15.00	......	1	......	17.00	......

In Fig. 6 and Table XVI the correlation between the anal and dorsals combined of both broods is represented graphically. Increase in the dorsal and anal elements are represented by distances away from the point of junction of the horizontal and vertical line respectively. The dotted diagonal line represents the condition of perfect correlation between the two fins. The line y is erected at the mean of the dorsal fin and line x at the mean of the anal rays.

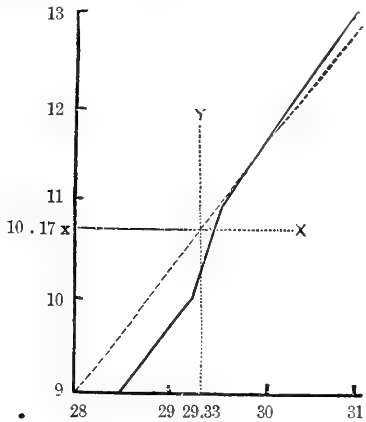


Fig. 6.

TABLE XV.

	Average No. of Dorsal Spines and Rays.
Specimens with 9 anal rays	28.50
Specimens with 10 anal rays	29.20
Specimens with 11 anal rays	29.53
Specimens with 12 anal rays	30.24
Specimens with 13 anal rays	30.85

From the latter half of Table XV the correlation between the spinous and soft dorsals may be obtained. Here it is seen that when the one dorsal increases, the other decreases. This condition shows that within certain limits these two kind of structures are convertible into each other and may replace each other.

SUMMARY.

1. In *Etheostoma caprodes* the males are more variable than the females in the ratio of .507 : .468. In *Etheostoma nigrum* the females are more variable than the males in the ratio of .402: .454.

2. The specimens of both species in Turkey Lake differ from those in Tippecanoe Lake in every structure examined.

3. The variation in the two species is determinate for the lake, that is, both species are modified in the same way by the same lake with but one exception.

4. This difference is not the result of selective influence, but apparently the direct effect of the environment.

5. The successive broods vary with the varying conditions of the year in which they are born.

6. The variations in the fins are correlated as follows:

   a. When the dorsal spines increase in number the dorsal rays decrease in number.

   b. When the anal rays increase the dorsal spines, the dorsal rays and the sum of the elements in the two dorsals increase.

The Origin of Cave Faunas. By C. H. Eigenmann.

[Abstract.]

There are two prominent views of the origin of the cave faunas and of their degenerate eyes.

The following from Ray Lankester presents one of these views: Supposing a number of some species of arthropod or fish to be swept into a cavern or to be carried from less to greater depths in the sea, those individuals with perfect eyes would follow the glimmer of light and eventually escape to the outer air or the shallower depths, leaving behind those with imperfect eyes to breed in the dark place. A natural selection would thus be effected. In every succeeding generation this would be the case, and even those with weak but still seeing eyes would in the course of time escape, until only a pure race of eyeless or blind animals would be left in the cavern or deep sea.

2. "The existence of these blind cave animals can be accounted for only by supposing that their remote ancestors began making excursions into the cave, and, finding it profitable, extended them, generation after generation, further in, undergoing the required adaptations little by little."—Herbert Spencer, Popular Science Monthly, XLIII, 487 and 488.

The first of these views is based on two facts, as everyone familiar with caves and their faunas will readily agree. These facts are, first, the author's lack of knowledge about caves and his disregard of the nature of the animals inhabiting them.

The second of these theories is more nearly applicable to the blind fishes. A partial adaptation to do without eyes is found in those species inhabiting the swamps of the Southern States. The eyes of Chologaster cornutus are very simple. In the species living under rocks and in caves, Ch. agassizii, there is a high development of the tactile organs, with a more perfect eye than in those living in the open. These fishes were adapted to do in part without light before they entered the caves and before their eyes had become seriously degenerate.

With the subsequent suppression of the eye in darkness natural selection can not have operated, as Lankester supposed, for species of the Amblyopsidæ with well-developed eyes still live in the caves by the side of those with mere vestiges of eyes.

Amblyopsidæ, whether blind or seeing, if kept in an aquarium darkened at one end seek the dark. They were not swept into the caves, but entered them deliberately and avoided coming out into the light. In short, they were able to establish themselves in caves because they were able to do without light, having simplified eyes and highly developed sense organs; they do not possess highly developed sense organs and degenerate eyes because they were accidentally swept into caves. The further degeneration of the eye in total darkness and the greater perfection of the sense organs are separate questions.

The Amblyopsidae and Eyes of Blind Fishes. By C. H. Eigenmann.

[Abstract.]

Our knowledge of the eyes of the North American blind fishes is based on the result of gross dissections of Amblyopsis made by Wyman before 1872 and on a brief account of the eyes of two specimens of Typhlichthys by Kohl (1895). Kohl's specimens, coming from Missouri, were made to do duty for the blind fishes in general. His paper is poor in the material examined and entirely perverse in his interpretation of the conditions observed. He does not state the habitat of his specimens. A comparative study of the eyes of Typhlichthys from Mammoth Cave and from Missouri led me to suspect that his specimens came from Missouri, and in this I found I was correct. The Typhlichthys inhabiting the underground streams of Missouri is very different from that inhabiting Mammoth Cave, and, unfortunately for the generalizations of Kohl, the difference lies in the structure of the eye.

The North American blind fishes are especially favorable for the study of degeneration and of many questions bearing on the origin of cave faunas because they have seeing representatives living in the open and others living with them in the caves.

The members of the Amblyopsidæ and their distribution is as follows:

Chologaster cornutus. Abundant in the lowland swamps of Southern States.

Chologaster agassizii. Subterranean streams in Tennessee and Kentucky and probably identical with the next.

Chologaster papilliferus. In springs of Union and Jackson counties, Illinois.

Amblyopsis spelaeus. Widely distributed in underground streams in the Ohio valley.

Typhlichthys subterraneus. Subterranean streams, chiefly south of the Ohio River.

Typhlichthys rosæ. Subterranean streams west of the Mississippi.

All have been examined except the Chologaster agassizii. Chologaster papilliferus possesses the most highly developed eye, but even in it there are many signs of degeneration; in Chologaster cornutus the outer nuclear and inner nuclear layers have each been reduced to a single series of cells, and the ganglionic layer to cells widely separated from each other. The lens and vitreal body are still apparently normal. In all the other species examined the lens and the vitreal cavity are minute or absent.

The ganglionic layer is, in Amblyopsis and T. subterraneus, a central, solid mass of cells; in T. rosæ even this has disappeared, and the eye has been reduced to 0.040 mm.—0.050 mm., or to one-third the diameter of the eye of T. subterraneus. The result of degeneration is not the same on the same layers in the different species. The degeneration is not the result of arrested development or of ontogenic degeneration. The eye of the blind fish reaching its greatest point of degeneration in T. rosæ, is the result of phyletic degeneration, begun before the fish entered the caves. The degenerate eye is not primarily due to the cave habitat. The eyes of those species living in the light are prophetic of the eyes of those living in the dark.

A New Blind Fish. By C. H. Eigenmann.

[Abstract.]

In the caves of Missouri lives a species of Typhlichthys. It is known from the description of Garman of its outer form, the description of its habits by Miss Hoppin and from the description of its eye by Kohl. In external characters it is very similar to Typhlichthys subterraneus from the Mammoth Cave. It differs from that species widely in the structure of the eye. This trans-Mississippi species has been named rosæ for the rediscoverer of the California Typhlogobius, a pioneer in the study of Biology among women, Mrs. Rosa Smith Eigenmann.

THE HABITS OF AMBLYOPSIS. BY C. H. EIGENMANN.

THE BLIND SALAMANDERS OF NORTH AMERICA, WITH SPECIMENS.
BY C. H. EIGENMANN.

NOTES ON THE EMBRYOLOGY OF PARAGORDIUS (GORDIUS) VARIUS (LEIDY).
BY ALBERT B. ULREY.

[Abstract.]

During the latter part of last summer I had the good fortune to find a lot of eggs of *Paragordius (Gordius) varius* (Leidy). This small thread-worm is familiar to nearly every one as the common horsehair worm found in streams, ponds and frequently in watering troughs.

The life history of the worm is known, in a general way, to all zoölogists. It is well understood, of course, that the very common superstition regarding the origin of the worm from the horse's hair has no more foundation in fact than a superficial resemblance.

There are three well-marked phases in the life history of Gordius. First, a free living larval stage. Second, a parasitic phase in which the host is (a) some aquatic insect, and later on (b) more commonly the fish becomes infested by feeding on the insect containing the larvæ. Third, the adult or sexually mature stage.

While the general course of development has been known for a number of years, there still remains much uncertainty concerning the details of its development, and there is absolutely nothing known as to many points in its life history. As a result of these gaps in our knowledge of these animals their relationships are not well understood. Some investigators believe that their affinities are with the segmented worms, while others maintain that they are to be grouped with the Nematodes.

It was with the belief that a more complete knowledge of the details of development of these forms might throw some light on their systematic position that I began this study.

The work is beset with numerous difficulties, among which may be mentioned the extremely minute size of the egg and the well-known difficulty of sectioning eggs of this character. I have given my attention thus far mainly to the study of the living eggs and larvæ and the methods which would enable me to section them successfully. I have made a series of photographs of the living embryo from the time of the first segmentation of the egg to the adult larval stage. A series of sections has also been made corresponding to the stages represented by the photographs.

While engaged in this part of the work some facts were demonstrated which it was believed might have some value and be of general interest to the Academy at this time.

The following notes are presented as a slight contribution to our knowledge of the embryology of the American forms of Gordiidæ:

1. Concerning the early cleavage of the egg there has been not a little disagreement among authors. Villot maintains that the cleavage is regular, while the figures of Camerano show that there is much irregularity. In a series of photographs of the eggs of *Paragordius (Gordius) varius* (Leidy) it is clearly seen that the first segmentation is total and the resulting spheres are approximately equal in size. A large number of eggs were observed showing equal segmentation. The sections prepared also show this method of division.

In other series of the photographs are shown:

2. The development of the egg until an oval mass of cells, the blastula, is formed.

3. Segmenting eggs still inclosed in the mass which binds them together into threads.

4. Surface views of the formation of the gastrula.

5. The larvæ still within the egg membrane.

6. The larvæ freed from the egg membrane, some with the proboscis extended and others in which it is retracted.

The embryos were all photographed while living except the specimens showing the protruded proboscis.

The figures, together with drawings of the sections prepared, will be published later.

"Quicksand Pockets" in the "Blue Clay" of South Bend. By W. M. Whitten.

The public water supply of South Bend comes from artesian wells driven to a water-bearing gravel 60 to 80 feet below the surface of the St. Joseph River. In this gravel the water is under a pressure sufficient to raise it about 25 feet above the river.

The impervious stratum which confines this water is locally known as blue clay. This deposit is from 13 to 50 feet in thickness, and the territory in which wells can be obtained which flow at approximately the same level, indicates that it is several miles in extent.

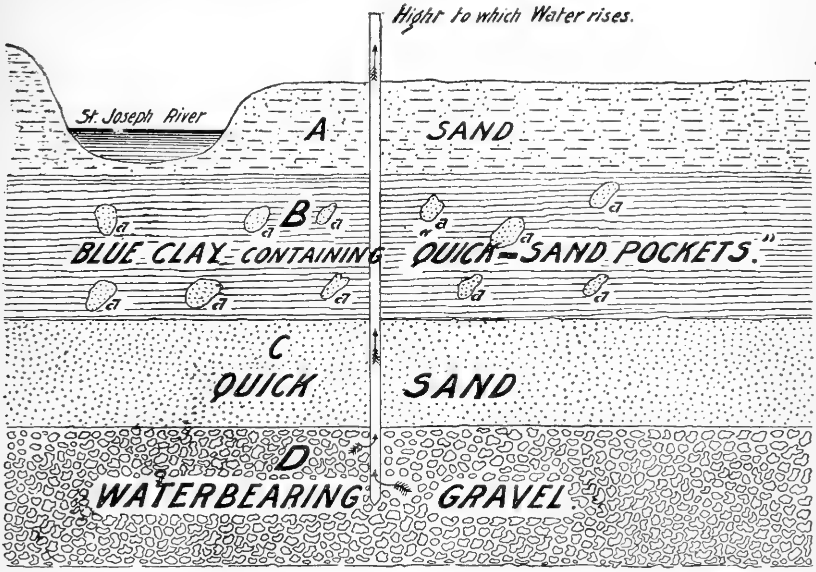
Between the blue clay stratum and the water-bearing gravel is a deposit of what is locally known as quicksand, which varies in depth from 10 to 40 feet.

Throughout the deposit of blue clay, distributed somewhat like boulders in the drift, are numerous masses of the quicksand, which are locally known as "quicksand pockets." These are of all shapes and vary in size from a few cubic inches to many cubic yards.

The record of borings of well No. 21 shows the following strata:

Sand	20 feet.
Blue clay	31 feet.
Quicksand	24 feet.
Gravel	16 feet.

And may be represented by the following:



A—Surface soil sand.
B—Blue clay containing "quicksand pockets."
C—Quicksand.
D—Water-bearing gravel.
a, a, a, a—Quicksand pockets.

Both the clay and quicksand are entirely free from pebbles, so much so that notwithstanding they contain a large percentage of lime (10 to 14 per cent.), the ingredients are so finely pulverized that no damage has ever been known to occur from the formation of quicklime in burning wares made from them. The clay is almost entirely free from grit and the quicksand contains only extremely fine sand. These facts indicate that both have originally been deposited in quiet water. There is, however, no indication of stratification to be found in the clay, but on the contrary the entire deposit (so far as it has been observed) has the appearance of having been greatly disturbed and subjected to a kneading process. Moreover, the presence of these detached masses of quicksand in the body of clay precludes the supposition that the mass as a whole remains as originally deposited.

Chemically the clay and quicksand differ much less than any one acquainted with their characteristics would imagine, as the following analysis shows:*

	Quicksand. *Per Cent.*	*Blue Clay.* *Per Cent.*
Water and carbonic acid	18.03	17.38
Silica (SiO_2)	49.48	45.89
Lime (CaO)	10.66	13.44
Magnesia (MgO)	7.69	7.67
Alumina (Al_2O_3)	7.80	9.05
Iron oxid (Fe_2O_3)	5.30	5.68
Titanic oxid (TiO_2)	.27	.21
	99.23	99.32

In general appearance, also, the two are quite similar, yet, on close examination, the limits of the "pockets" are easily determined. Within these limits the material is distinctly "quick sand," while without the limits it is as distinctively clay. The clay deposit has been used quite extensively. It makes a fine white or cream-colored building brick, and when vitrified makes a good street paver. It is also used in the manufacture of Portland cement. But manufacturers find that an admixture of the quicksand makes the clay difficult to mold by machinery, prevents the uniform vitrification necessary for good street pavers, and totally destroys its value as an ingredient in the manufacture of Portland cement. These quicksand pockets, therefore, injure the commercial value of the deposit.

The presence of these pockets, filled as they are with material differing from that which immediately surrounds them, but identical with that which underlies the deposit, together with the fact that the clay appears to have undergone much disturbance, suggests the possibility that their contents may have come from the quicksand stratum beneath the clay.

The base of the clay has not been reached by any excavation and, therefore, no opportunity has been afforded to examine the lower portion of the deposit, but at the town of Mishawaka, four miles east of South Bend, I had an opportunity during the past season of observing somewhat similar phenomena. In a sewer trench on Second street, in that town, there appears a deposit of clay from one to four feet thick, overlying

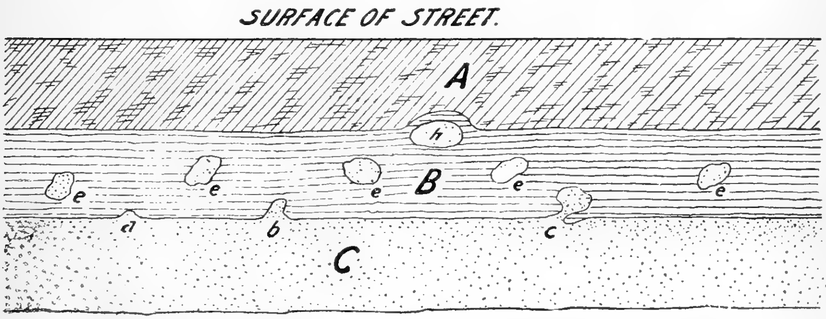
* Analysis by Wm. M. Whitten, Jr., B. S., M. S.

clean sand. Six hundred feet of the trench passed through this formation and in this distance I saw quite a number of masses of sand embodied in the clay, forming "pockets" of sand in this clay deposit very similar to the "quicksand pockets" in the "blue clay" of South Bend.

These masses of sand were compact, and as distinct from the clay as a boulder of granite or limestone would be, and their boundaries were almost as sharply defined.

At the base of the clay there appeared what might be taken for sand pockets in different stages of formation. At one point there was a slight, but distinct upward curve in the clay, which was filled with sand, as at "a" of the following "section." This might be taken as the beginning of a sand "pocket." At another point this was more pronounced, as at "b," and may have been a sand pocket further developed; and at one point there was a mass of sand about one foot in diameter almost completely surrounded with clay, leaving a neck of only two or three inches of sand to connect it with the sand deposit below, as at "c."

SECTION OF SEWER TRENCH ON SECOND STREET, MISHAWAKA.



A—Surface soil, unstratified.
B—Clay deposit containing sand "pockets."
C—Sand, water laid.
a—Sand pocket beginning.
b—Sand pocket further developed.
c—Sand pocket nearly complete.
e, *e*, *e* and *h*—Sand pockets complete.

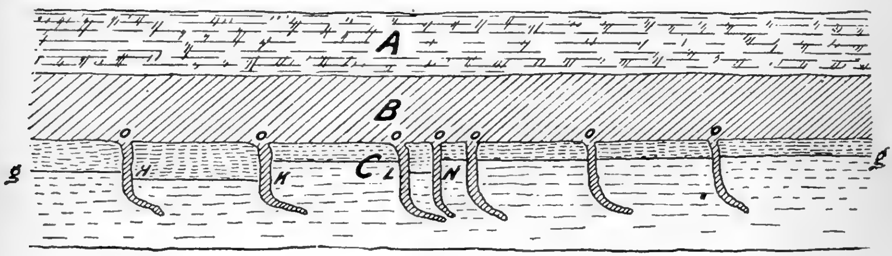
At points where pockets were near the top of the clay there seemed a tendency to raise the clay above the level of the body of that deposit, as at "h."

Soon after the meeting of the Academy the excavation of the trench further east on the same street disclosed another clay deposit in which all the different phases of sand pockets were present and constituted a much larger percentage of the mass.

These facts seem to indicate that these masses of sand have been gathered up from the underlying strata and raised partly or wholly through the clay to the positions in which they were found. If so, the same force might be invoked to fill the "pockets" in the "blue clay" at South Bend with the quicksand underlying that deposit.

It is difficult, however, to conceive of these detached bodies of sand retaining their distinctive character and a compact form while being transferred from the underlying strata to the positions in which they were found, unless they were solidly frozen during the process, for otherwise they would have lost their identity and simply become mixed with the clay. The best explanation of these facts that I can think of is to assume that during a retreat of the ice the sand deposit has been uncovered and solidly frozen, and in that state has been overridden by the re-advancing ice, at the base of which the clay was transported, and that frozen fragments of sand have been detached from the main body of that deposit and raised to the position in which they were found, in the same manner that fragments of rock, over which glaciers move, are said to become detached and raised by the movement of the ice.

Some plausibility is given to the above assumption by a study of the following section of a sewer trench excavated on Leland avenue, South Bend, in 1894. The trench runs north and south:



A—Shows surface soil, sand and gravel.

B—Clay deposit from 1 to 4 feet thick, unstratified.

C—Fine sand, containing distinct horizontal stratifications or markings, *g*, *g*, *g*, *g*, which are faulted at H, K, L and N.

o, *o*, *o*—Are dyke-like masses of clay extending down from the main body of clay into the stratified sand a distance of from 4 to 8 feet.

The dikes crossed the trench about N. 60 degrees E. and S. 60 degrees W. They were from 4 to 12 inches in width and were nearly vertical from the clay down to a depth of 2 or 3 feet, and then curved to the northward more and more as the depth increased. At their junction with the main body the clay was compact and solid, but further down it became lumpy, the lumps having the appearance of having been rolled and rubbed over sand, and intermingled with the lumps was an amount of sand increasing with the depth. The lower portion of the dikes had the appearance of having been filled by dry sand, and the clay lumps dropped in loosely from above.

At the junction of the dikes with the main body of clay the angle on the south side was rounded off while on the north side the angle was sharp, and was less than a right angle and in some cases became quite acute. The line of contact at base of the clay indicated that a rubbing movement had taken place from the north or northwesterly to the south or southeasterly. The lower half of the dikes were so nearly horizontal that they could not have been filled by clay and sand dropping from the top. From the nature of the fine sand it would be impossible to open crevices, or cracks, therein, to be filled with the clay from above, unless the sand were frozen solid. From these facts I conclude that the stratified sand must have been deposited with the horizontal markings continuous across the dikes, where they are now faulted. That in this condition the sand was frozen during an interglacial period, or a temporary retreat of the ice. While so frozen some convulsion opened cracks or fissures in the frozen sand to the depth of the dikes, and probably produced the faults in the horizontal stratification at the same time; that when so opened the fissures were so nearly vertical that clay lumps and sand from the top could drop to the bottom; that while in this condition the sand with its open fissures was overridden by ice, the base of which transported or shoved the clay over the sand, rubbing off particles of clay and sand to fall to the bottom of the crevices until the dikes were formed (and in this connection it may be of interest to state that in the bottom, or toe, of one of these dikes I found well preserved bits of wood).

That after the crevices were filled the sand, protected by ice and clay from the low temperature to which it had been exposed, gradually thawed out from below by the heat of the earth. That the movement of the clay was communicated, to some extent, to the sand beneath it, the surface moving faster than the lower strata, thus producing the curved position of the dikes and rounded edges on one side and the acute angles on the other side of the dikes, where they join the main body of clay.

I do not recall any "pockets" of sand in the clay in this trench, but at that time I probably should have given little attention to them had they been there, and this may be an instance of "seeing without perceiving," but the facts above stated clearly indicate that frozen sand may be expected to act as other rocks act under like conditions.

No surprise would be occasioned by finding a sandstone boulder raised from its bed and incorporated in the drift clay. The grains of sand may be united as firmly by congealed moisture as by some of the cements that unite the grains of sandstone, and therefore, if it be conceded that frozen sand may be overridden by advancing ice, it is not unreasonable to conclude that masses of the frozen sand might be detached from the main body and raised and incorporated in the drift in the same manner.

THE CADY MARSH. BY T. H. BALL.

Among the physical features of Lake County, Indiana, of interest to the scientific observer is one known as the Cady Marsh. It covers mainly what are now sections 28, 29 and 30, in township 36, range 8, west, and sections 25, 26, 27, 28, 29 and 30, in range 9, west, also in township 36.

It is now crossed by the Chicago & Erie Railway, and, in part, by the Grand Trunk. Three wagon roads now cross it, and one large ditch, the Hart Ditch, cuts its western expansion.

It was originally, that is, sixty-three years ago, when it was first seen by the white settlers, covered with water. It was considered dangerous for a man to undertake to cross it on horseback.

It lies between two of the great sand ridges of Lake County. These two ridges coming together some five miles from the east line of the county, define its eastern limit, and as the northern ridge runs nearly west into Illinois and the southern passes south of west also into the State of Illinois, the western expansion of this marsh joins with other lowland which on an early map of Indiana was called Lake George. The water in that so-called lake is said to have been from about two to seven feet in depth. This early Lake George has been drained by the great Hart Ditch, which passes from Dyer on the State line, and running a little east of north across five sections of land, once water, into the Little Calumet, makes a broad, deep cut in the northern sand ridge one mile west from Highland.

The Cady Marsh proper may now be best examined by passing along the road from the present town of Griffith to the old stage road along the north sand ridge. The distance across is little more than a mile. The road crosses section 26 and has a ditch on each side.

It is not probable that the composition of this marsh, as to its surface, is uniform, but there is, first, a layer of peat, from ten to sixteen inches in depth, then four feet of sand, below this about sixteen feet of clay and then gravel or sand. The depth to rock no one as yet probably knows. In early times, when covered with water, of course fires did not run over this marsh, but since it has become comparatively dry fires get started in some way; they cannot well be extinguished; and they have destroyed large areas of the peat surface, burning sometimes through an entire winter. Several years ago quite a quantity of this peat was dug or cut out and prepared for market, but it could not compete with coal and the industry was abandoned. From the southern sand ridge, along the road mentioned, sand now washes in large quantities, filling up the ditches along the road for forty or sixty rods. The flow of the water is toward the north and west. The ridge along the north end of this road, where the east and west road is reached, is about forty rods wide at the base and about forty feet to the crest of the ridge, so that an immense bank of sand lies along the north of this marsh, and just north of this bank comes the Little Calumet bottom land, which, between Highland and Hessville, is often in the spring flood times covered with water for a mile in width. The Chicago & Erie Railway crosses the Cady Marsh between Griffith and Highland. At present portions of this once wet, impassable marsh are cultivated and the land is quite productive. A few houses have been built on it, and it is becoming a valuable part of the cultivated area of Lake County. It was a great resort once for "bobolinks," but they have nearly deserted it now.

As to its formation, if, as seems probable, the water of Lake Michigan many years ago extended to the southern large sand ridge of Lake County and remained for quite a time stationary north of the great Highland, or old Stage Road ridge, then the sand now over this depression between the ridges, which depression was left full of water, was washed on probably from the southern ridge, as it is working on along the ditches still, as that ridge itself may have been washed up before the first recession took place, from the depths of Lake Michigan. The peat on that marsh now is a quite new or fresh formation, having come from the roots of the vegetation that sprang up when the water had largely receded.

But these operations of nature, of large interest always, and especially when we can observe them for a few years, are mostly speculative, rather than certain. The writer of this has had an opportunity to observe through the space of forty years, and therefore to know with certainty with what great rapidity, in some places, during heavy rainfalls, sand will be washed over a large area of bottom land. He has seen prodigious quantities of sand and gravel removed quite a distance by successive rainfalls.

Preliminary Work for the Approximate Determination of the Time Since the Retreat of the First Great Ice Sheet.

By Glenn Culbertson.

It was with the desire of obtaining a close approximation to the time which has elapsed since the retreat of the Kansan or first great ice sheet that, during the past summer, the two most important waterfalls—Clifty and Butler—in the vicinity of Madison and Hanover, Jefferson County, Indiana, were visited by me and the work to be described was performed.

The well-known Clifty Falls, over which the water leaps a vertical distance of seventy feet, was the first visited. Into drilled holes steel rods were driven vertically to the depth of twelve or more inches in the solid limestone of the stream bed at a distance from the precipice over which the water falls, and accurate measurements from the rods to the edge of the precipice were made and recorded.

Butler Falls, which is located about one-half mile south of Hanover, and over which the water falls eighty feet, was also visited and similar measurements made and recorded.

The falls in both cases are caused by the presence in the stream beds of very durable strata of limestone, chiefly of the Madison and Clinton formations, and which is of very uniform texture and hardness over the region referred to. The rate of valley growth toward the head is governed by the erosion or undermining of these rocks.

A steel rod was also driven horizontally into a drilled hole in the even-textured but softer rock of the vertical or overhanging walls of the amphitheater-like excavations beneath the falls, and in each case a mark was made upon the rod from which from time to time measurements can be made as the gradual weathering of the rock continues.

The excavations beneath the falls are caused chiefly by the saturation of the rock by means of spray and mist carried by waterfall breezes or winds during winter floods, when frosts follow and complete the process. Better results will in all probability be obtained from the measurements of the weathering beneath the falls than from those upon the edge of the precipice, since the rate of weathering beneath is quite uniform and since the wearing away of the softer rock beneath determines largely the amount of breaking away and falling of the harder rocks above.

By means of data obtained from such measurements during a period of years, a close approximation to the rate of valley erosion can be obtained. These data taken in connection with the length of the valleys from the Ohio River to the falls, which in the case of Butler ravine or valley is approximately 3,100 feet, and in the case of Clifty is 11,000 feet, will give us an approximation of the time since the streams began work on the valleys.

The topography of these valleys and of the surrounding region, which gives every indication of the youthful stage of erosion, together with evidence of another character, indicates that these valleys have been eroded since the retreat of the Kansan or first great ice sheet. This ice sheet not only covered all the region referred to, but crossed the Ohio Valley, if the valley were there at that time, and advanced at least twelve or fifteen miles beyond in Trimble County, Kentucky. All the region was planed off to essentially the same level, and there are now within one and a half miles of the Ohio River undrained flats produced by glacial action.

A close approximation to the time required to erode these valleys should, then, give a fairly accurate approximation of the number of millenniums that have passed since the disappearance of the first great ice sheet from the borders of the glaciated region. This period, even approximately obtained, will be of great importance in ascertaining the causes of glacial periods, as well as being of interest in the discussion of other problems of import.

Note on Fault Structure in Indiana. By Geo. H. Ashley.

It has long been a prevalent idea with Indiana geologists that this State is practically without faults or fault structure. Prof. E. T. Cox, for many years State Geologist, says in his last report:* "Not a single true fault, or upward or downward break and displacement of the strata has yet been discovered." Prof. John Collett, so long a student of Indiana geology, says in describing Badger Bros.' mine in Sullivan County:† "An interesting feature of this mine was the discovery of a vertical dike or wall of inclusive clay, one foot wide, running a little east of north. This is the only fault, though here only a separation, that I have met with in the coals of Indiana," etc.

In view of such statements by the earlier workers, repeated by some of the more recent workers, it was not without surprise that the writer found that faults not only existed in the State, but were abundant and well exposed. It may be that this is truer of the coal measure area than of the rest of the State. Certain it is that the extensive mining of the coal gives a better opportunity for the study of these phenomena than is granted elsewhere, and further, the displacement of a coal bed is more readily noted when seen in a bluff or other exposure than a displacement in most other rocks.

The figures accompanying this note are selected from sketches and photographs made while engaged in a survey of the coal area of the State for the Department of Geology and Natural Resources. Time did not suffice for a detailed study of the faults, only such notes being obtained as were made incidental to the main work.

In a general way it may be said that the phenomena observed consist of normal faults, either single, double, wedge or step faults, sometimes accompanied with little or no notable crushing, or again accompanied by intense and extensive crushing, to be followed by the intrusion of clay or other substances; reversed or overthrust faults, crushed and thickened strata, due to tangential pressure, oblique jointing of strata due to the same cause, old surface crevices filled from above. Normal faults predominate, with down-throws varying from a few inches to forty feet or more. In number it may be judged from their abundance wherever extensive

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*1879. 8th, 9th and 10th Ann. Rep. Geol. Surv. of Ind., p. 3.

†1871. 2d Ann. Rep. Geol. Surv. of Ind., p. 205.

mining or good bluff exposures give an opportunity to observe them, that Indiana contains thousands of faults of appreciable down-throw. In some districts there is hardly a mine that does not contain from one or two to several dozen.

In their relation to the general structure the normal faults divide themselves into four classes, as typified in figures 1 to 4, plate I. In the first type, which might be called the monochinal fault, the fault is simply a fractured monocline, the down-throw of the fault usually not being as great as the differences of level above and below the monocline. Such a fault may consist of a single break or of two or more breaks, known as a step fault. In some cases the same fault will show as a single break at one point and as a step fault at another point, as in the case illustrated by figures 6 to 8 of plate I. Figures 5, 9 and 10 further illustrate the same type of fault.

In the second type of fault the hade is in the opposite direction from the general dip. Figures 11 to 13 of plate I illustrate this type of fault. Such a fault usually occurs as a series of breaks, resembling a broken arch, a type of fault common in the western part of the United States.

Faults of the two types mentioned constitute a class that appears to be due to the uneven settling of the Illinois basin area. These faults, taken as a whole, do not appear to have any uniformity in the direction of down-throw or of strike. However, if only the larger faults be considered, a majority of them trend between northeast and northwest and have the down-throw to the west. There are so many notable exceptions that it can not be considered as a rule. Thus, in Martin County, from Shoals westward, the dip is nearly everywhere observed to be strongly to the west, yet so many faults with the down-throw to the east occur in that region that the strata are higher five miles west of Shoals than at Shoals.

In the third and fourth types the faults appear to be due to quite local causes, as the strata a short distance on either side are on about the same level. Figure 14 of plate I and figure 2 of plate II illustrate the two types, respectively. The difference between the faults of the first two types and those of the last two are very well shown in the effect on the driving of entries in the mines. Thus, a six-foot fault of the first type necessitates driving the entry up or down until it is at least six feet above or below its old level, according as the fault is approached. A six-foot fault of the third type can be passed with little or no change of level in the entry. A possible cause of faults of the last two types is thought to be the unequal subsidence of underlying basins of coals. In a basin where, as is usually the rule, the coal is quite thick in the center and very thin on the edges, the actual shrinkage is much greater in the center of the basin than on the edges. A certain percentage of this shrinkage is known to take place after the deposition of the overlying beds. Where a channel has been cut in the coal and filled with sandstone an irregular belt results which resists compression much more than the coal adjacent and might lead to a fracturing of the overlying strata, as the subsequent unequal settling takes place. This is suggested merely as one possible cause of such faults. These faults are very irregular as regard course and direction of down-throw, frequently crossing each other, sometimes being very short and again traceable in two or more adjacent mines. In the Dugger Mine, Sullivan County, three faults cross each other in the same vertical line at one place.

Considering the structure of the faults at the fault line, it is found that frequently the fault line appears sharp and clear cut, as in most of the figures of plate I, and it is only on very close examination that any crushing can be detected. In other cases, however, the crushing effect has been intense for several feet, or even several yards, on either side of the fault line. This often occurs where the down-throw is hardly noticeable. At such a fault there is very apt to result an intrusion of clay or other material, making clay veins, sandstone veins, etc. Figures 3 to 9 of plate II illustrate this. The way the pressure has forced the clay out in irregular streamers, as in figures 3 and 4, or simply forced it into the coal in irregular masses, as in figure 5, give some idea of how completely pulverized the adjacent coal often is. The sandstone veins, or "rock spars," as they are usually called in the mines, are generally very hard sandstone. Apparently they are somewhat similar in origin with the clay veins, though we are not entirely satisfied that such is the case. In figure 14 a surface crevice has had coal washed in, making a coal vein of a certain type.

If such a crevice be considered as probably resulting from fault action in the neighborhood it would indicate that some of the faulting took place during the laying down of the coal measure rocks. This vein occurs about ten feet below the lowest worked coal in Indiana.

Overthrust faults and accompanying phenomena are not common, as compared with normal faults. They are met with in various parts of the field, but the amount of accompanying crushing often renders the structure

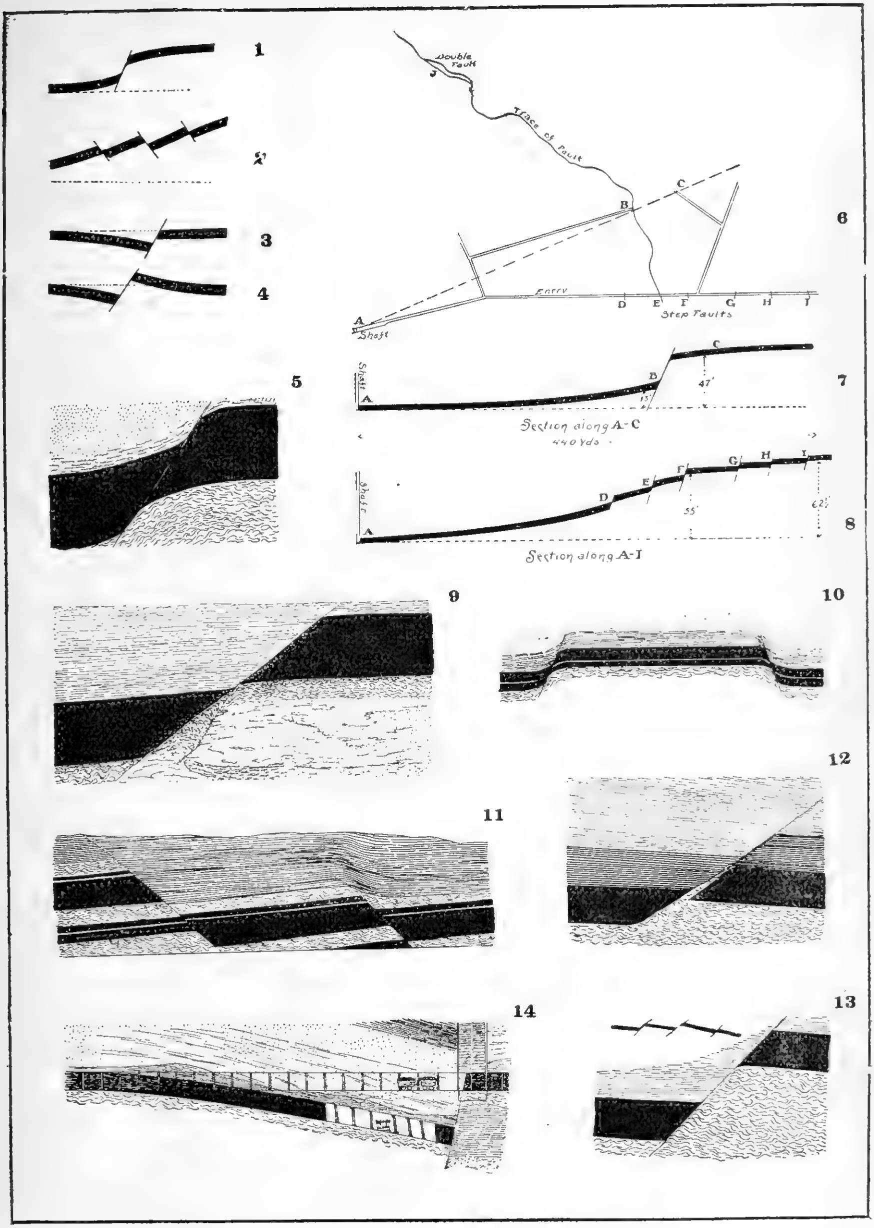

1
2
3
4
5
Double Fault
J
Trace of Fault
B
C
Entry
D
E
F
G
H
I
Step Faults
A
Shaft
6
Shaft
A
B
C
47'
15'
7
Section along A-C
440 Yds.
Shaft
A
D
E
F
G
H
I
55'
62½'
8
Section along A-I
9
10
11
12
13
14

Plate I.

obscure and their study difficult. Illustrations of such faults are given in figures 11 to 13. In figure 13 the lower of two beds twenty feet apart has been forced an unknown distance over the upper bed. Some of the accompanying phenomena consist of oblique jointing, induced in the strata, and in the vertical thickening of coal beds, as illustrated in figure 10.

DESCRIPTION OF PLATES.

Plate I—Typical normal faults:

Fig. 1. Type of monoclinal fault. See figures 5 to 10 inclusive.
2. Broken arch type of fault. See figures 11 to 13, inclusive.
3. Type of fault shown in figure 14.
4. Type of fault shown in figure 2 of plate II.
5. Fault in Fairview Mine, Clay county.
6-8. Fault in B. B. C. Co.'s No. 10 Shaft. Map and sections.
9. Fault on Otter Creek, 3 miles north of Brazil. From photo.
10. Double fault in Peerless Mine, Vigo county.
11. Double fault on Big Vermillion River, near Hanging Rock.
12. Fault on north fork Otter Creek, near Coal Bluff, Vigo county.
13. One of series of faults in Fairview Mine.
14. Fault crossing shaft in Jackson Mine, Clay county.

Plate II—Irregularities due to faulting; clay, sandstone and coal veins; overthrust faults and crushed structure:

Fig. 1. Combined fault and "roll," Monarch Mine, Clay county.
2. Fault of type 4, Dugger Mine, Sullivan county.
3-4. Clay veins resulting from faults. P. Co. C. Co.'s No. 6 Shaft, Parke county.
5. Clay in old fault plane, Winsett Mine, Vermillion county.
6. Clay vein, Dugger Mine, 10 feet from and running parallel to large fault.
7. Sandstone vein, Ray Mine, Vigo County. Shows displacement in another entry.
8. Sandstone vein, Mecca No. 1 Mine, Parke county.
9. Sandstone vein, B. B. C. Co.'s No. 8 Mine, Clay county.
10. Showing structure of coal bed thickened to nearly four times normal thickness by lateral pressure, in region of overthrust faults, Columbia No. 3 Mine, Clay county.
11-12. Coal bed greatly disturbed, Lee's Mine, Vermillion county.
13. Overthrust fault, Columbia No. 4 Mine, Clay county.

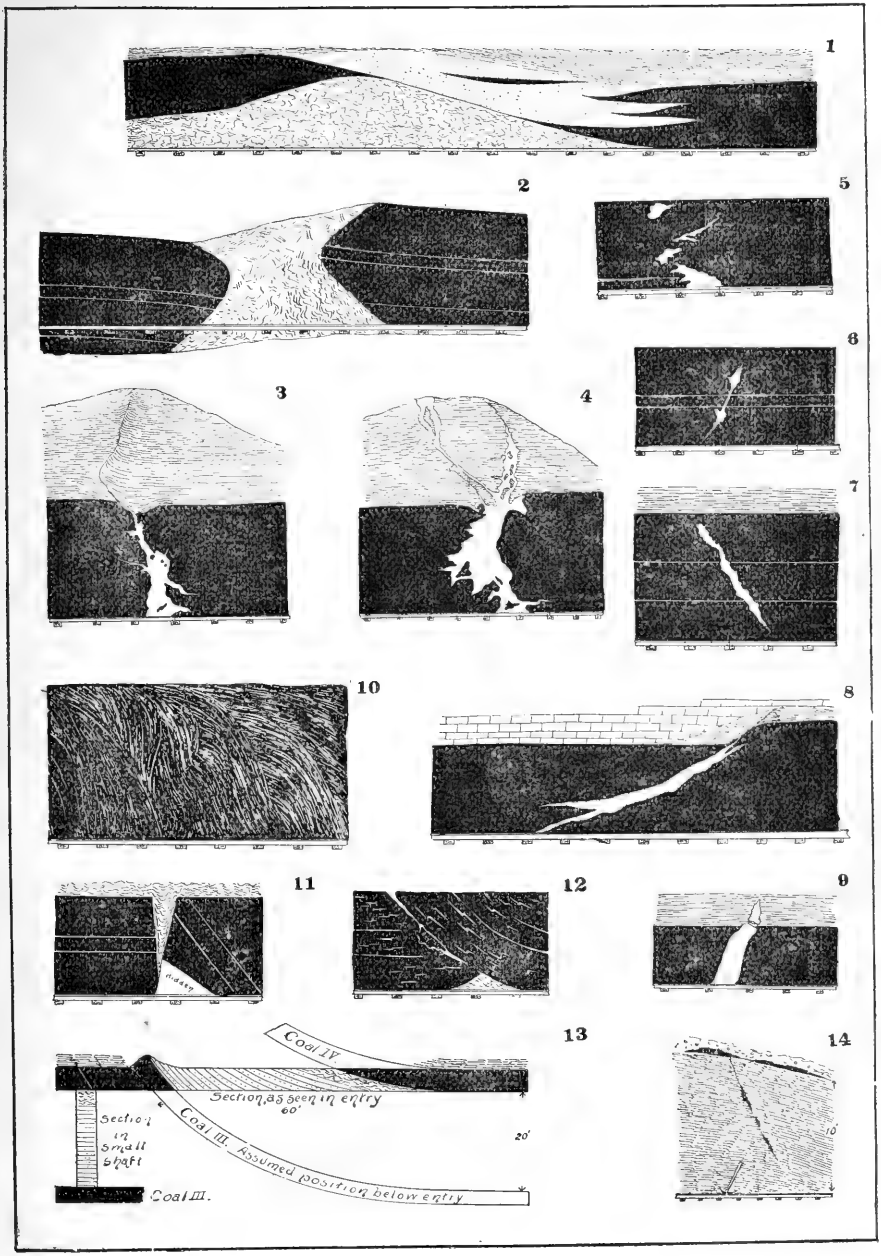

1
2
5
6
3
4
7
10
8
11
12
9
13
14
Coal IV.
Section as seen in entry
60'
Section in small shaft
Coal III.
Coal III. Assumed position below entry
20'
10'

PLATE II.

14. Coal vein, Gart. No. 5 Mine, Clay county.

Figure 11 of plate I and figures 5, 11 and 12 of plate II are from sketches by Mr. E. M. Kindle, assistant on coal survey. With the exception of figures 1-4, 6-8, 10, 14, of plate I, and figures 13 and 14 of plate 11, all the figures are in the scale of 1 inch=10 feet.

As it was the writer's purpose in this paper merely to call attention to one of many interesting geological features of the coal regions which appear to have escaped notice, no descriptions of individual faults are given here, as they will be included in the monograph on the coal of Indiana, in preparaton.

NOTES ON THE GEOLOGY OF MAMMOTH CAVE. BY R. E. CALL.

A GEOLOGICAL SECTION ACROSS SOUTHERN INDIANA FROM HANOVER TO VINCENNES. BY J. F. NEWSOM.

[Abstract.]

During the field season of 1896 a geological section was run through the center of the row of townships numbered 3 N, from Hanover on the Ohio River to Vincennes on the Wabash.

The profile was run by means of the vertical arc and aneroid barometer. The dips of strata and elevations as shown may be depended upon within the limits of these methods.

The geological formations and the topography crossed by this section are typical of almost the entire southern portion of Indiana.

The lowest rocks to be found in the section are the soft beds of the Cincinnati group along the Ohio River. These beds are about 250 feet thick in the region near Hanover.

Overlying the Cincinnati beds are the hard limestones of the Clinton, Niagara, and Corniferous. It is this combination of limestones overlying the soft Cincinnati beds that causes the bluffs along the Ohio River, and the waterfalls that are so common in that region.

THE EASTERN PLATEAU.

Overlying the limestones is the Devonian black shale. The region underlain by the limestones, and the easternmost edge of the Devonian black shale is a high gently rolling plateau, sloping very gently to the west. This may very properly be called the eastern plateau region of southern Indiana. The dip of the rocks is westward, and varies from 20 to 46 feet per mile.

The Devonian limestone (corniferous) passes beneath the drainage near the west line of township 3 north, 8 east.

The Devonian black shale outcrops over a strip of country some twelve miles wide and forms for the most part low hills and flat plains. Its thickness at Scottsburg is 120 feet.

THE EASTERN LOWLAND.

The Knobstone Group, with the Goniatite limestone overlies the Devonian black shale. The base of this group is easily eroded. These easily eroded strata, combined with the easily eroded black shale, have been largely worn away, leaving the low, comparatively level country to be found through southern Indiana, immediately east of the Knobs and hills of Floyd, Clarke, Washington, Scott, Jackson, Bartholomew, and Brown counties. This region may properly be called the eastern lowland.

From the eastern edge of the eastern plateau (800 feet above tide), to the center of the eastern lowland (570 feet above tide at Scottsburg) the country slopes gently to the west, the slope corresponding almost exactly with the dip of the rocks.

THE MIDDLE PLATEAU.

The top of the Knobstone group is made up of sandstones. These are overlain by the Lower Carboniferous limestones. These strata resist the action of the weather, and consequently are directly responsible for the "Knobs," which are not a range of hills, but the more or less abrupt eastward face of a gently westward dipping plateau, which may be styled the central plateau. This plateau has been deeply cut by its streams.

THE SINK-HOLE REGION.

Overlying the Knobstone group are the thick beds of Lower Carboniferous limestones, in which are found the caverns of southern Indiana. This limestone region is completely pitted with sink-holes, and practically the whole of its drainage is by underground channels. This region has a gradual westward slope. It is the sink-hole region of Indiana. There is a noticeable increase in the size of the sink-holes in going from east to west as the limestone beds become thicker.

THE WESTERN PLATEAU.

West of the sink-hole region formed by the limestones, is the very rugged region to be found immediately east of the Coal Measures. The hills of this region are capped by the Mansfield sandstone or Mill-stone grit, to which formation they are in large part due. The region in which the Mansfield sandstone is the controlling formation may be termed the western plateau. This plateau has been very much dissected by its streams.

THE WESTERN LOWLAND.

Overlying the Mansfield standstone are the soft and easily eroded beds of the Coal Measures. These beds have been already worn down very near to their base level of erosion, if indeed they have ever been much above that level.

CONCLUSION.

(a.) In passing from east to west across southern Indiana, three prominent topographic features are crossed, and these features are the results of combinations of strata as follows: (1) the high eastward escarpment along the Ohio River caused by a thick series of easily-eroded calcareous shales overlain by thick and resisting limestones; (2) the high eastward facing escarpment with its outliers to the east, known as the "Knobs;" this escarpment is the result of a thick series of soft clay and sandy shales, protected by sandstones and resisting limestones. Along the line under discussion this escarpment is 28 miles west of the escarpment along the Ohio; (3) the high hills of Martin County, which are the result of a series of limestones and sandstones capped by more resisting sandstones and which do not rise as an escarpment from the east, but become gradually higher, owing to the resisting nature of their lowest beds. The distance from the Knobstone escarpment to the highest hills capped with the Mansfield standstone is about thirty miles.

(b.) The structure of each of these topographic features where crossed by the section is essentially the same in different stages of development; i. e., that of a dissected plateau, sloping gently to the west. In the eastern, or Devonian limestone plateau, in the region of the Ohio, dissection has scarcely begun, as none except the streams flowing directly into the Ohio have deep gorges, and these are only from one-half to one and a half miles long; in the middle, or Knobstone plateau, dissection has progressed much further than in the eastern one, while the western or Mansfield sandstone plateau has been completely dissected by its streams.

It is possible that this peculiarity in the amount of erosion that has taken place in these different plateaus is the result of the character and former upward extension of the overlying formations in each case.

(c.) The top of the eastern plateau where crossed by the section is 800 feet above the sea, that of the middle is 820 feet, and that of the western 880 feet above tide, while but a short distance to the north or south the topographic sheets show the elevations of these plateaus to correspond even more closely.

These closely corresponding elevations point strongly to the conclusion that the present topography of southern Indiana has developed from an old base-level. The present topography, however, might have been developed from a plain of deposition, or a combination of the two.

The Knobstone Group in the Region of New Albany. By J. F. Newsom.

During the field season of 1897 the Indiana University Geological Survey undertook the delineation of the upper and lower limits of the Knobstone group, and working up of the general geology of that particular formation. Work was begun in the extreme southern part of the State. It is with only a few of the points of interest that were developed in that region that this paper deals.

HEIGHT AND CHARACTER OF KNOBS.

The knobs of the extreme southern part of Indiana do not form a range of hills, strictly speaking, but are the irregular eastern escarpment of a plateau, ranging in height from 200 to 400 feet. From the top of this escarpment the slope to the west is very gradual, while to the east there are often numerous sharp outlying hills, almost as high as the main plateau.

The general course of the eastern face of the Knobstone escarpment from where it is cut through by the Ohio River, in township 6 S., is but little east of due north for about 30 miles, where, in township 1 S., 6 E., it turns to the west around the headwaters of Muddy Fork of Silver Creek.

In the region immediately west of New Albany there are many high eastern outliers, which make the country very broken and rugged. A short distance northwest of New Albany there is a noticeable decrease in the number of outliers. The escarpment in this region is typical, with a high plateau to the west, an abrupt eastward slope with a descent of 200 to 400 feet, and a comparatively low level country to the east.

GENERAL CHARACTER OF THE KNOBSTONE GROUP.

The Knobstone group in Southern Indiana is made up of a thick series of clay shales, sandy shales and sandstones. The shales predominate at the base of the group, while the sandstones predominate at the top. The series of rocks was originally called the Knobstone by Owen because of their peculiar "knobs," or, as their name implies, knob-like hills that are often left by its erosion at a greater or less distance east of the main escarpment.

Overlying the upper sandstone layers of the group are the Lower Carboniferous limestones, which, with the sandstones below, form a protecting cap for the thick underlying shales. When the streams cut through this overlying cap of limestone and sandstone they quickly cut down through the underlying soft shales and form deep gorges. Because of the slight westward dip of the strata the eastward flowing streams always cut through these shale beds.

DIP.

The knobstones and overlying limestones dip gently to the west or southwest. The westward dip, in sections 1 and 2, township 3 S., 5 E., was found to be 41 feet per mile. This dip is very gentle, but it is sufficient to entirely control the drainage. Thus it is noticeable that the water-shed between waters flowing east directly into the Ohio and those flowing southwest and reaching that stream after many miles is at the very eastern face of the plateau. In Floyd and Harrison counties it is often no more than one or two miles from the Ohio. The streams flowing to the west have a gentle fall, following in the main the dip of the strata. The resulting topography is of the gentle rolling type common in many limestone regions. The streams flowing to the east, on the contrary, are short, and flow through deep, narrow gorges that have been cut down through the soft knob shales. These valleys are often from 250 to 300 feet deep.

THE UPPER LIMIT.

The parting between the top of the Knobstone group and the overlying Carboniferous limestones crosses the Ohio River near the east side of township 6 south, 4 east. The line of parting in the extreme south is low in the hills and is covered by cliff debris and alluvium, consequently it cannot be continuously traced in going northward until township 4 south, 5 east, is reached.

From the point where it enters Indiana the upper limit of the group runs northward along the eastern face of the escarpment on the west side of the Ohio, seldom extending more than two miles back from that stream. On account of its dip it is carried successively higher in the hills, reaching their very tops in township 2 south, 6 east. From here northward the base of the limestone is found at the tops of the hills.

The line of parting from its southernmost exposure, runs northward in a very sinuous line through townships 6, 5, 4, 3 and 2 south, 5 and 6 east, until it reaches section 31, township 2 south, 6 east. At this point, which is four miles west of New Albany, the outcrop turns westward and follows along the south side of Indian Creek until it is carried beneath the drainage level and crosses to the north of that stream in section 20, township 2 south, 5 east. There are low dips showing a very low anticlinal fold in the southeastern part of 2 south, 4 east, and the southwestern part of 2 south, 5 east, and it may be to some extent due to this structural feature that Indian Creek and its tributaries have cut through the limestones, exposing the underlying Knobstone, through these townships.

After crossing to the north side of Indian Creek the upper parting between the Knobstone and limestone turns again and runs to the northeast in a very sinuous line. It gets higher in the hills until it again reaches their tops in section 17, township 1 south, 6 east. Here it turns to the west and passes west of Borden and on across Blue River.

A glance at the accompanying map will show that the continuous line of outcrop as here described makes a bend to the west and then to the northeast, causing the knobstone to form the principal rocks in the valleys, at least nine miles from the true eastern face of the knobs in township 2, south.

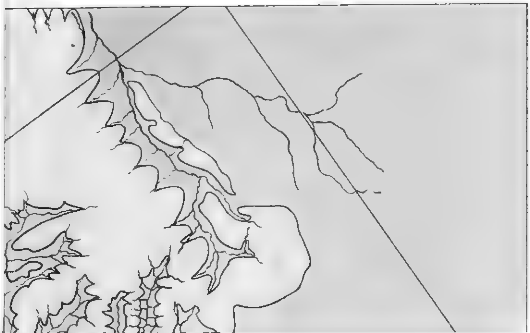
It is seen, also, that by no means all of the rocks of this immediate locality belong to the Knobstone, but that there are, included within the main line of outcrop, some large outlying limestone areas. These outlying limestones are, of course, only the remnants of the beds that at one time covered the entire region. As the process of erosion continues these limestone areas will gradually disappear. It will be noticed that to the south of the area of exposed Knobstones (in township 1 south) just described, there is a smaller area where the limestone has been cut through, but where it still completely encloses the exposed underlying sandstones. To the north, in the region of Borden, there is also a large area in which the overlying limestones have been almost completely removed, leaving but one small limestone area to the east of the main outcrop. These three areas illustrate very well three different stages in the process of the dissection and removal of the topmost strata of a plateau.

In conclusion, attention should be called to the distribution of springs.

Since the rocks composing the Knobstone group are of such a nature as to prevent the free circulation of water, springs are by no means common in that formation. At the top of the formation, however, the line of parting between the limestones, which do permit the free circulation of water, and the underlying impervious sandstones, is a natural spring horizon. Along this line of parting springs are very common, and except at the extreme eastern edge of the Knobstone escarpment, where the limestone has been eroded to a very thin edge, they are to be found in almost every small side ravine.

E 8 E

2 N



ALBANY SHEET)

A UNIVERSITY

ICAL SURVEY

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EWSOM, DIRECTOR

—1897—

SSISTANTS

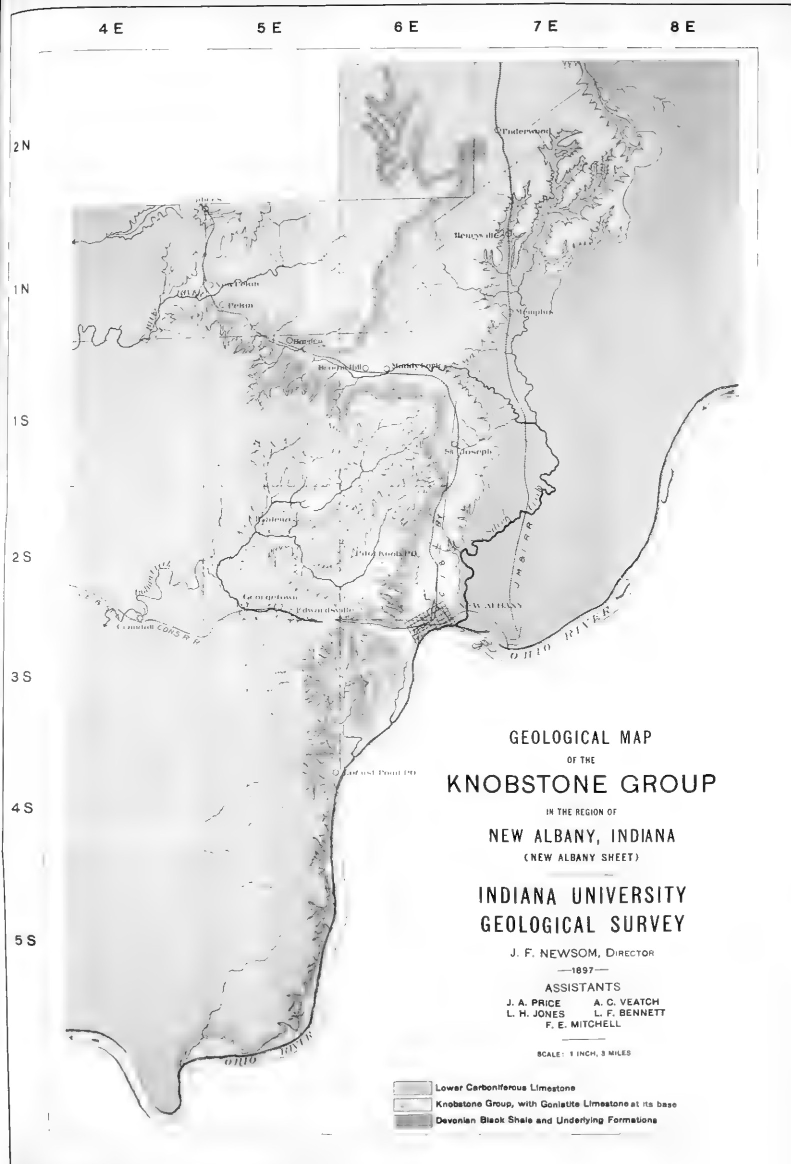
E	A. C. VEATCH
ES	L. F. BENNETT
E. MITCHELL	

LE: 1 INCH, 3 MILES

stone

niatite Limestone at its base

Underlying Formations



GEOLOGICAL MAP
OF THE
KNOBSTONE GROUP
IN THE REGION OF
NEW ALBANY, INDIANA
(NEW ALBANY SHEET)

INDIANA UNIVERSITY GEOLOGICAL SURVEY

J. F. NEWSOM, DIRECTOR

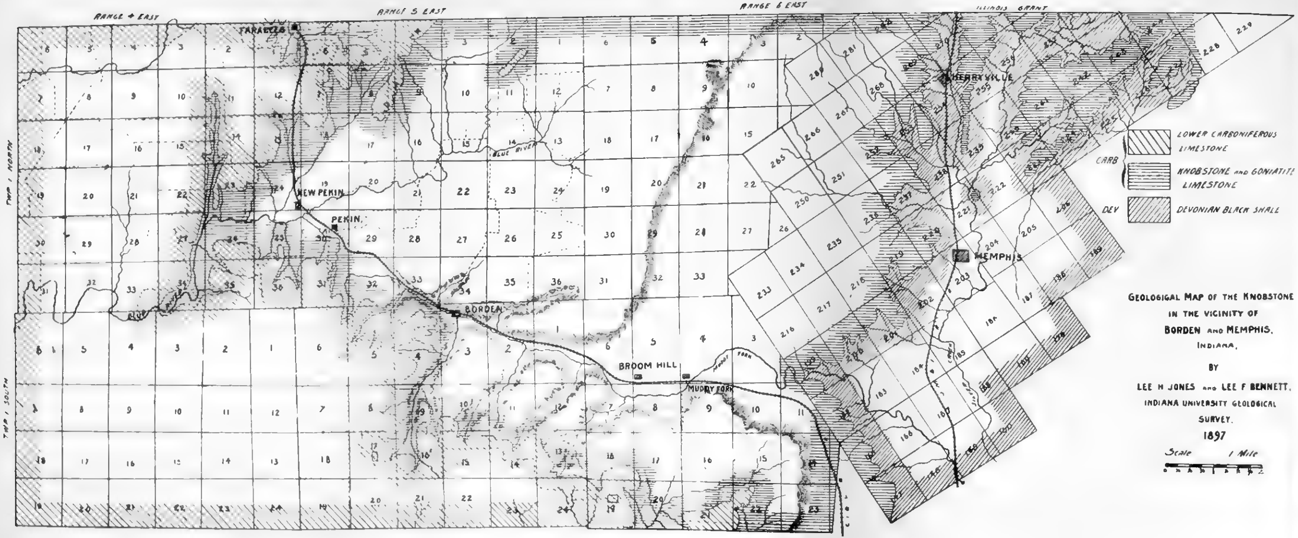
—1897—

ASSISTANTS

J. A. PRICE A. C. VEATCH
L. H. JONES L. F. BENNETT
F. E. MITCHELL

SCALE: 1 INCH, 3 MILES

Lower Carboniferous Limestone
Knobstone Group, with Goniatite Limestone at its base
Devonian Black Shale and Underlying Formations



GEOLOGICAL MAP OF THE KNOBSTONE IN THE VICINITY OF BORDEN AND MEMPHIS, INDIANA, BY LEE H JONES AND LEE F BENNETT, INDIANA UNIVERSITY GEOLOGICAL SURVEY. 1897

The Upper Limit of the Knobstone in the Region of Borden. By Lee H. Jones.

During the last field season of the Indiana University Geological Survey the line of parting between the Lower Carboniferous limestone and the Knobstone group was traced through township 1 south, 4, 5, and 6 east, and 1 north, 4, 5, and 6 east. In this locality there was found to be an interesting distribution of the knobstone group; and it is with this feature that this paper deals.

In general, the upper limit of the knobstone has a trend of north slightly east, keeping within a short distance of the Ohio River from the point where it crosses that stream in township 6 south until a point five miles west of New Albany is reached. Here it turns to the northeast and runs to section 22, 1 south, 6 east, where it turns directly northwest.

This line is continuous, with but slight deviation to the east or west, except in 2 south, 4, 5 and 6 east, where the overlying limestone is entirely cut through by the westward-flowing streams, leaving many isolated limestone areas capping the Knobstone hills.

From the point where the line of parting between the top of the Knobstone and the overlying Harrodsburg limestone (Lower Carboniferous) turns west, in section 22, it runs northwestward in a continuous line until it passes west of the headwaters of Muddy Fork of Silver Creek, in township 1 south, 5 east, one and one-half miles south of Pekin.

From this point it runs westward and a little to the south on the south side of Blue River, until it reaches section 33, 1 north, 4 east, where it passes beneath the drainage level and crosses to the north side of that stream.

Again the line of parting turns to the northeast, and owing to the elevation of the rocks in that direction, it is gradually brought back to the tops of the hills. At the northeast corner of section 4, township 1 north, 5 east, it again turns to the west. A glance at the map will readily show that the upper limit of the knobstone in the area under discussion forms a westward indentation, with its wider part to the east.

The overlying Harrodsburg limestone in the vicinity of section 22, township 1 south, 6 east, is very thin at its eastern and northern edges, running out to a feather edge along the line of parting. In this immediate locality the line of parting is from one to two miles from the eastern and northern face to the knob escarpment; to the west, in section 18, same township, the parting runs out nearer the bluffs along the south side of Muddy Fork of Silver Creek. From this point westward it is carried lower and lower in the hills by the general westward dip of the rocks until it passes beneath Blue River.

It will be noticed that the head waters of Muddy Fork of Silver Creek and Blue River overlap by some ten miles, and that the line of parting passes to the south of Muddy Fork of Silver Creek and to the north of Blue River.

The region between these two streams has had its limestone removed by their combined erosion. It is interesting to note that this is the only locality in the Knobstone region where there is such an overlapping of east and west flowing streams.

The knobs of this locality are formed by a high plateau sloping gently to the west, with an abrupt slope to the east, and north on the south side of Muddy Fork of Silver Creek, and a steep south slope on the north side. The hills immediately north and south of Blue River are less rugged.

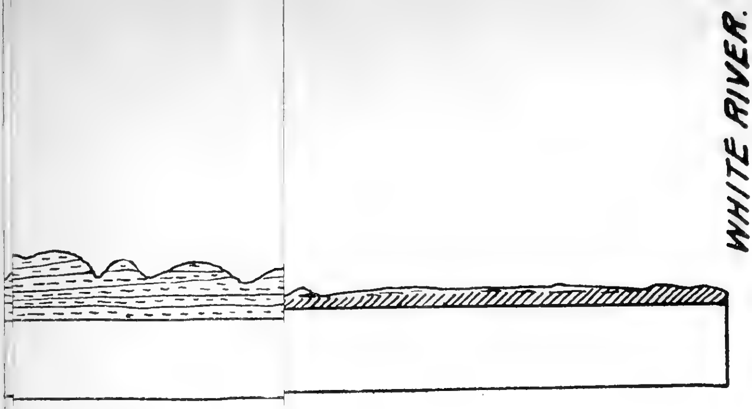
In a general way the lower limit of the group runs in a direction somewhat parallel to that of the upper limit, making a slight westward bend from block 182 to block 192 of the Illinois grant, where it crosses Muddy Fork of Silver Creek and turns to the northeast.

It will be noticed that the lower limit does not make as great a bend to the west as does the upper limit. This is due to the fact that the lower limit is very near to the drainage level of the country. In this region the lower limit of the Knobstone shale is marked by the greenish Rockford Goniatite limestone, which has a thickness of from ten inches to three feet. Immediatey below the Goniatite limestone is the Devonian black shale.

Four Comparative Cross Sections of the Knobstone Group of Indiana.

By L. F. Bennett.

In connection with the geological work of the State University in 1897 several cross sections of the Knobstone group were made in order that its width and the distribution of the rocks forming it might be discovered. It is with four of these comparative cross-sections that this paper deals. The elevations were obtained by means of the aneroid barometer and the locations by placing and inquiry. As the main object



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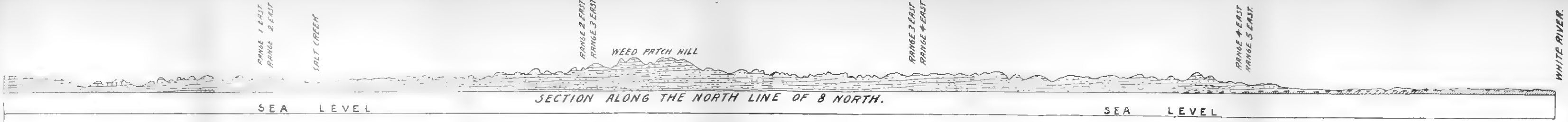
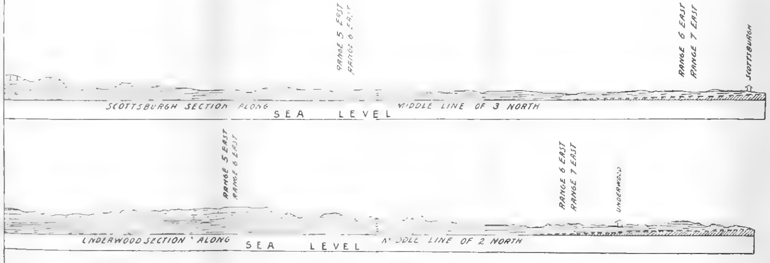




ST JOSEPH SECTION
TWP 1 SOUTH 6 EAST.

FOUR COMPARATIVE CROSS-SECTIONS
OF THE
KNOBSTONE GROUP
OF
INDIANA

By
L. F. BENNETT AND OTHERS OF THE
INDIANA UNIVERSITY GEOLOGICAL SURVEY.
1897.

LEGEND

- LOWER CARBONIFEROUS LIMESTONE
- KNOBSTONE GROUP
- GONIATITE LIMESTONE
- DEVONIAN BLACK SHALE

HORIZONTAL SCALE: 1 MILE
VERTICAL SCALE: 1200 FEET

was to work out the topography, not so much attention was paid to the geology, but in most places it was worked out with some degree of accuracy.

This formation is made up of sandstones and shales. Above it is the Subcarboniferous limestone; below, the New Albany black shale. In the south the shale predominates; in the north, the sandstone. At the base of the formation is a layer of hard greenish-blue limestone, called the Rockford Goniatite limestone. This layer is very persistent and varies from ten inches to three feet in thickness. In the southern part of the State, north to where it is covered by a glacial clay, the eastern limit of this limestone is but a few feet below the general surface of the country, being covered by soil and clay to the depth of eight to twenty feet.

None of the sandstone is pure. It is mixed with considerable quantities of muddy shale and also contains small quantities of iron, which is shown in the weathered rock. The shale is muddy, easily eroded, and contains large quantities of iron nodules. In most places there is a gradual transition from the shale to the sandstone; just where one leaves off and the other begins it is difficult to tell. This is especially true in the southern part of the State. Farther north there are alternating beds of shale and sandstone, but the beds of shale are much the thinnest.

The formation shows an entirely different topography in the south from that in the north. It makes up the knobs of Floyd, Clark, Scott, Washington and Jackson counties and the hills of Bartholomew, Brown and Morgan counties.

In the south, in Floyd and Clark counties, the knobs present a bold face toward the east; they are steep and vary from 200 to 400 feet in height. East of the knobs the country is comparatively level and farther north outlying hills are found. These outliers in northern Jackson and in Bartholomew counties extend eastward from the main range of hills five or six miles.

In the four cross-sections under discussion the dip of the rock was not determined, but it was measured in other places and found to be 26 feet to the mile to the west.

The southernmost of the four cross-sections was run in township 1 south, range 6 east, a short distance south of St. Joseph, a small town on the J., M. & I. R. R., six miles north of New Albany. The Subcarboniferous limestone is found on the top of the easternmost knob or hill and is 250 feet above the Goniatite limestone to the east. This is about the narrowest place in the formation. It is two miles wide. Here the sandstone is 90 feet in thickness and the muddy shale over 200 feet. Both the sandstone and shale have been worn away as fast as the limestone has receded. For this reason the hills are steep and the country to the east is low and flat.

This is not quite a typical section for this region, because limestone is seldom found on the hill farthest to the east. It is usually found a mile or more west of the eastern face of the knobs.

The next section to the north, the Underwood section, was run along the middle line of township 2 north. It begins on the west side of the Illinois grant and runs west 13¼ miles. On the east are found low hills called the Guinea knobs, none of which are over 150 feet above the surrounding country, and most are much lower. On the tops of some glacial gravel is found, on others clay, due to the decomposition of muddy shale. Fifty feet above the Goniatite limestone there is a layer of muddy shale containing iron nodules, and higher up there are layers of blue shale, much bluer than is the usual color.

For four and a half miles west of the Guinea knobs the country is generally level; then the outliers of the western knobs are reached. They are made up entirely of shale and clay, except the last hill to the west, which contains sandstone at the top. The country continues rough for three miles and only one valley of any consequence is crossed; it is the valley of the Big Ox Fork. The last ascent is 250 feet where sandstone 190 feet in thickness is found. Typical of this formation, the sandstone at some depths is much muddier than at others; and in this hill, at the top, the sandstone is much muddier than about 100 feet down, where for a few feet it is comparatively pure, then it gradually grows muddier until it grades into a sandy shale, and still farther down into a nearly pure shale.

For the next two miles the country is nearly level; it then becomes more broken until the limestone is reached, four and one-half miles west of the first sandstone hill. Just beneath the limestone there is a layer of blue shale; below this is the sandstone.

The next section, the Scottsburgh section, was run along the middle line of township 3 north. It begins in the vicinity of Scottsburgh and continues westward 13½ miles. It is comparatively level for 10 miles, the country being covered with alluvium and glacial and residual clays. The first hill of any consequence is capped with muddy sandstone, the second by the Subcarboniferous limestone.

A comparison of this section with the Underwood section shows a considerable difference. In the latter there is but little level country; the Guinea knobs are on the east; the outliers of the western knobs are four and a half miles to the west, and it is several miles farther before the limestone is reached. In the Scottsburgh section there are no outliers, and limestone is found on the second hill. The knobs make a great bend to the west in running through township 2 north and township 3 north, hence the difference in the two sections.

The Weed Patch Hill section was run along the north line of township 8 north. It is 30 miles long. It begins at the White River, two miles south of Columbus, runs across Brown County over Weed Patch Hill and ends in Monroe County.

For two miles and one-half the country is level and is covered to a depth of 30 feet or more with alluvium. The next four miles is rolling, the first two miles of which is covered with glacial clay, the latter with residual clay. A well section in the first hill shows the Goniatite limestone to be 40 feet above the surface; this is its eastern limit.

The higher hills begin six and one-half miles west of White River. The first hill rises almost abruptly 150 feet and is almost entirely made up of muddy sandstone. Throughout the rest of the section the hills are steep and high. In many places it is but 300 or 400 yards from one hill to the next, and the hollow between is 150 feet deep and sometimes deeper. Shale is found in the deepest hollows for the first six miles. Farther on no shale is found except in thin layers at various heights in the sandstone. This is one peculiarity of the rock in this section. The sandstone greatly predominates; in fact, it is 22½ miles wide, and through it there are these thin beds of muddy shale. All gradations between the nearly pure sandstone and shale are found and in several places the sandstone is nearly blue.

Weed Patch Hill was made 1,135 feet high by the barometer; the correct height is 1,147 feet. Sandstone is found all the way to the top. It is much higher than any of the hills on either side.

Seven miles farther west Salt Creek valley is crossed; it is one-half mile wide. Still farther west, a mile and a half east of the west end of the section, there is a layer of fossiliferous limestone. It is found at the base of the hill in the sandstone, and is 15 feet thick and is made up almost entirely of crinoid stems. One-fourth of a mile farther west, at the base of the next hill, there is a fifteen-foot layer of blue shale.

It would naturally be supposed that the watershed is at the highest point, namely, at Weed Patch Hill, but this is not the case. It is about two miles west of the eastern face of the hills. Most of the streams crossed east of Weed Patch Hill flow to the southeast and empty into Salt Creek several miles below the place where it is crossed by this section. The location of the watershed, perhaps, gives a clue as to the position of the rocks that once covered this region, which is now an excellent example of a completely dissected plateau.

This last section is typical of the Knobstone north of White River. The limestone has pushed farther to the west, leaving a wide area covered by the Knobstone, most of which is the muddy sandstone. The sections south of White River are also typical for that region. The St. Joseph section has very little sandstone exposed and the shale greatly predominates.

A glance at the map will explain why it is there are so many hills in the north in the Knobstone group; it is because of the thickness and wide distribution of the sandstone.

Notes on Indiana Geology. By J. A. Price.

In connection with the field work in geology at Indiana University during the last season the distribution of a strip of limestone, usually surrounded by outcrops of the Knobstone group and lying east of the main mass of the Lower carboniferous limestone of Indiana, was in part outlined. It is with this unconformity that this paper deals.

In the Report of the State Geologist for 1896, page 391, a strip of limestone commencing at Limestone Hill, eight miles southeast of Bloomington, and extending east of south through Heltonville to and probably beyond Fort Ritner, Lawrence county, is referred to.

Without attempting to solve the conditions under which this limestone was laid down, it is desired to touch upon the extent and relative position of this limestone strip and the Knobstone north and south of the points referred to in the report.

In sections 26, 27, 34 and 35, township 4 north, 2 east, Washington County, between Twin Creek, which flows north through sections 35, 36 and 25, and the East Fork of White River, which flows south through sections 22, 27 and 34, lies a point of land one and one-half mile long and one mile wide. The top of this point is formed of limestone, which varies in thickness at different places around the point.

Near the center of section 34 the line of parting between the limestone and knobstone is 150 feet above the bed of the river. Farther north, near the south side of section 27, the line of parting is 140 feet above the river.

At the north end of the point of land in section 22 the line of parting is only 110 feet above the river, with 40 feet of limestone above, and at the northeast corner of the land the line of parting is only 60 feet above Twin Creek. At this point the overlying limestone is 100 feet thick.

At the south side of section 26 the knobstone is only 40 feet thick and is overlaid with 160 feet of limestone, while at the corresponding point on the west side the knobstone is 140 feet thick, with only 20 feet of limestone.

Near the bridge across Twin Creek in the northeast quarter of the northeast quarter of section 35 the line of parting is only 20 feet above the creek, and is overlain with 150 feet of limestone.

A well section near the northeast corner of section 27 shows the following strata: Soil, 35 feet; limestone, 10 feet; knobstone, 88 feet.

On the west side of a tributary of Twin Creek, at the east center of section 35, the line of parting is only 20 feet above the creek bed, while on the east side the hill is 190 feet high, without limestone. From the line of parting on the west side of the branch to the school house at the center of section 35 there is 150 feet of limestone, but from the school house west there is only a descent of 50 feet to the line of parting at the west side of the section. Fig. 4.

On the east side of the point of land between White River and Twin Creek the upper ledges of limestone form a cliff some 12 or 15 feet high. On the west side there is no cliff, and the exposures are covered over largely with debris.

In the center of section 26 is a point that extends to the southwest some 400 yards from the high sand hills east of the creek. The average height of this projection is about 100 feet. With the exception of 20 feet of knobstone at the base of this projection, the rocks are all limestone. The adjoining hill to the northeast rises 150 feet above the projection and is formed of knobstone.

On the north side of the projection and west of the wagon road are two ditches some 30 yards apart. In the ditch farthest east there is an exposure of knobstone and in the other an exposure of limestone, the line of contact coming somewhere between these two ditches.

Farther south, in section 1, township 3 north, 2 east, occurs the same unconformity. From the road through the west side of section 1 to the line of parting in Clifty Creek is a descent of 150 feet. In going east to the head waters of one of the side branches of Rush Creek there is only a fall of 50 feet to the line of parting. The two points where the line of parting was observed are not over one-half mile apart.

Farther north, in 5 north, 2 east, the limestone occurs on the west side of Guthrie's Creek. The line of parting is 25 feet above the creek bed, and from the line of parting to the top of the hill is 100 feet. All the exposures are limestone.

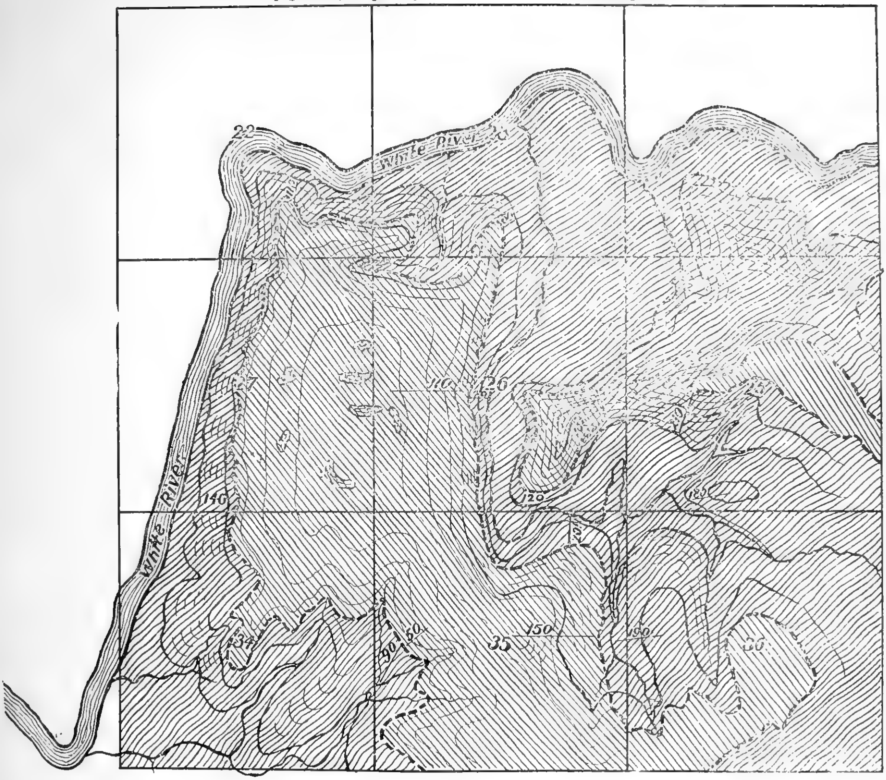
Near the top of the hill there is exposed a thick ledge of limestone which forms a small cliff corresponding to the cliff on the west side of Twin Creek. Farther west, where the streams have cut through the limestone and exposed the edges of the strata, no such cliffs are formed. Farther west the lighter the deposit for one-half mile or more, where it begins to thicken and dip gently to the west. A cross-section of the body of limestone is triangular in shape, with the base jutting against the knobstone, the altitude along the surface and the hypotenuse bedding upon the knobstone. (Fig. 2.)

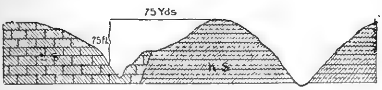
Farther north, near the center of section 10, township 9 north, 1 east, the division between the knobstone and limestone crosses the road about 150 yards west of where the road turns to the north. The knobstone does not occur in the hill to the east, although this hill is 50 feet higher than the road. In a gully 250 yards northwest of the road, where the line between the pale-colored clay of the knobstone and the red clay of the limestone crosses it is the line of contact between the two formations. One hundred yards southeast of the center of the southwest quarter of northeast quarter of section 10 the displacement is found. (Fig. 1.)

In general this belt of limestone seems to extend north and south, or north 10° west, and has been observed from near Mount Carmel, in section 1, township 3 north, 2 east, Washington County, to near Unionville, in section 10, township 9 north, 1 east, Monroe County.

At all points of observation the limestone had the same general shape—thick on the east side, with but slight modifications in going west for a short distance, then gradually thinning out, and connected or disconnected with the limestone west of it.

TOWN 4 N. RANGE 2 E.





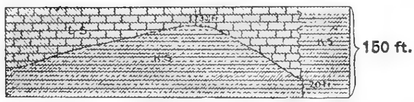


Fig. 1. Cross Section in Sec. 10, 9 N. 1 E.

Fig. 2. Diagramatic Section of the l. s. belt.

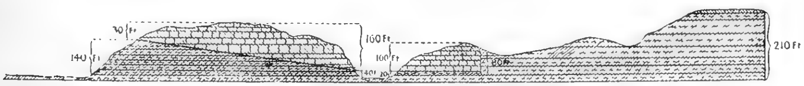
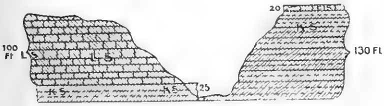


Fig. 3. Cross Section South of the Center of Sections 25, 26 and 27.



No l. s. on top.

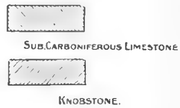


Fig. 4. Cross Section in Sec. 35, 5 N. 2 E.

Figures 2 and 3 show an unconformity. These figures, however, are in part ideal, as the actual line of contact, or unconformity (if such it is), was not observed, being covered with debris. It is not possible, from the data in hand, to say surely whether this strip of limestone owes its existence to an unconformity or a fault.

The peculiar distribution of this strip of limestone effects the topography of that section of the country in which it is found. West of the easternmost line of contact the country is rolling, with quite a number of sink holes, characteristic of limestone formations. East of that line of contact the country is very rough; the streams are in deep, narrow ravines characteristic of the knobstone area.

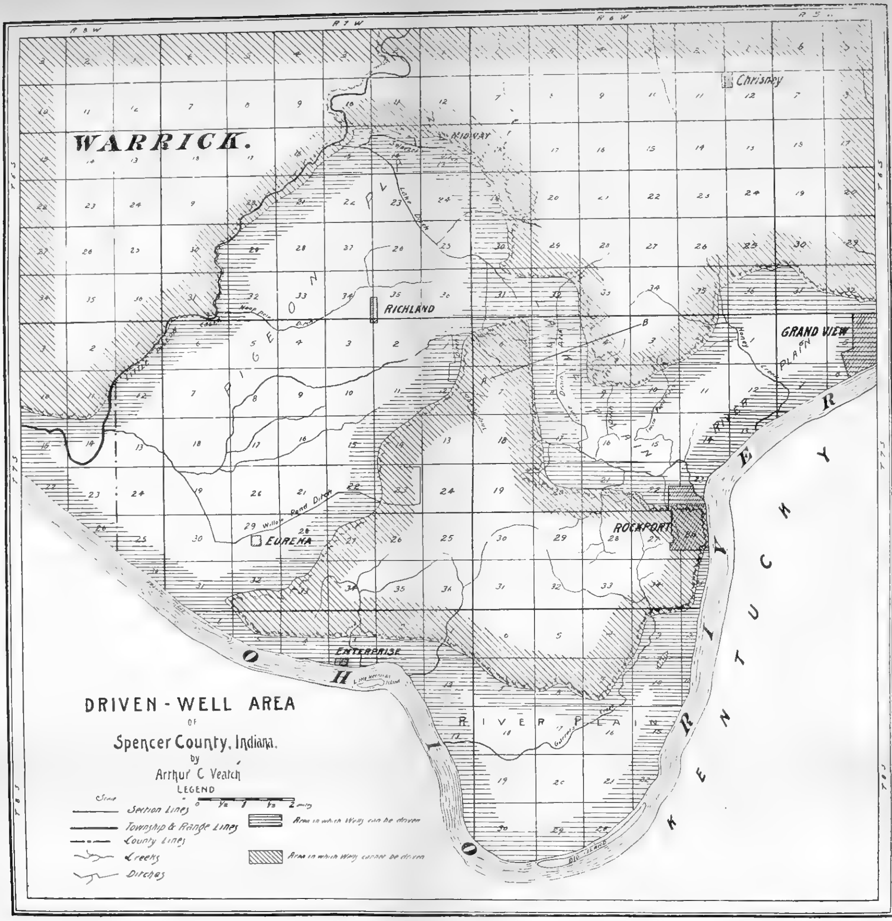
The present location of the streams running north and south near this point is due largely to the unconformity, they following the line of contact, or, having cut below the limestone level, are following channels in the knobstone.

An Old River Channel in Spencer County, Indiana. By Arthur C. Veatch.

All that portion of Spencer County south of the line which separates townships 5 south from that of 6 south, and west of a line running north and south through Grandview, may be divided into two physiographic regions, a plain and a hill region.

The plain may be subdivided into three parts. First, a broad, level plain extending southwest along the western boundary of the county. (See Fig 1.) It has the same general trend as Little Pigeon Creek, and will therefore be called Pigeon Plain, although it is not now occupied by Little Pigeon Creek. The two valleys are separate and distinct. Where Pigeon Plain enters the northern part of the area under consideration it is about two miles wide. It gradually widens until at Midway it is about four miles, at Richland five, and continues at this width until it enters the second division of the plain region, the river plain of the present Ohio.

Only a portion of this river plain comes properly under the present discussion of Spencer county, as a part lies in Kentucky. Taking the two parts together, the average width of the plain is between four and five miles. That portion which lies in Indiana is very irregular on account of the meandering course of the river. It includes all land locally termed the



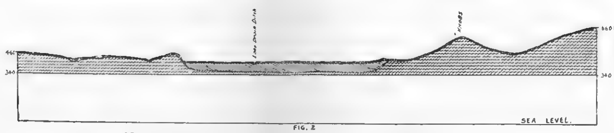


FIG. 2

SECTION SHOWING FILLING OF CHANNEL IN LAKE PLAIN ALONG LINE A-B MAP OF DRIVEN WELL AREA.

Horizontal Scale 1320 ft Vertical Scale 320 ft

CARBONIFEROUS STRATA ALLUVIUM LOESS AND RESIDUARY EARTH

FIG. 3.

SECTION ACROSS PIGEON PLAIN.

Legend same as Fig. 2. Horizontal Scale 1320 ft Vertical Scale 640 ft river bottoms. Near Grandview the bottoms are about a mile wide. At Rockport the river strikes against the bounding bluffs, so the Indiana portion of the valley is here reduced to zero. The river then rebounds toward the bordering hills in Kentucky, which it strikes at Bonne, Harbor Hill, a few miles below Owensboro, Ky. This makes the plain north of Owensboro three and a half miles wide. At Enterprise, seven miles below Owensboro, the plain is only half a mile wide. Three and a half miles below Enterprise the river plain merges into Pigeon Plain.

The third portion of the plain enters the river plain between Grandview and Rockport, its southern portion including part of the town of Rockport. It is here three miles wide. Narrowing down to two miles, it extends westward three miles, where it turns abruptly northward and enters a gorge a full mile wide. After going three miles in this direction it turns westward again and enters Pigeon Plain two miles east of Richland, in section 31, township 7 south, range 6 west. The narrow part of this plain was occupied by a shallow pond of water when this country was first settled. This pond was called "The Lake" by the early settlers. For this reason this division will be called Lake Plain, although, as will be shown later, the lake is a result and not a cause of the plain.

These three plains so merge into one another that it is impossible to tell where one begins and the other ends. The difference in levels of all three is very slight, not being over 25 feet except in four places, where Honey Creek, Lake Drain Creek, Enterprise Creek and Little Pigeon Creek have cut narrow, deep channels in the yielding alluvium.

The surface is so nearly level that large portions either are or were swampy. In Lake Plain is Swan Pond, covering portions of sections 5, 8 and 32; township 7 south, range 6 west, drained by Swan Pond Ditch; a marshy place, near Silver Dale Church, drained by Kennedy's Ditch, and the Lake covering sections 5, 8 and 32, township 7 south, range 6 west, drained by a ditch constructed in 1896 and emptying into Lake Drain Creek.

In Pigeon Plain is a series of ditches draining the "black land" north of Midway; Sweezer's Ditch, draining Sweezer's Pond; Lake Ditch, draining a swampy area in sections 24 and 25, township 7 south, range 7 west, and sections 19, 30 and 31, township 7 south, range 6 west; Cow Pond and Hoop Pole Ditches, draining land near Richland, and Shoptaugh and Willow Pond Ditches, draining land farther south. In the river plain there are many small ditches draining low tracts.

The hill region occupies all land not occupied by the plain. It will be seen from the location and interconnection of these plains that the hill land is divided into two parts. One, a roughly triangular portion, has its apex at the meeting of the Lake and Pigeon plains and its base roughly a little below the southern line of township 7 south. This region is characterized by a great number of hills rising on an average from 40 to 60 feet above the plain. The highest part of the triangular hill land is in Rockport, near the junction of Lake and River plains, where the hills rise 120 feet above the plain. The next highest is at the junction of Pigeon and River plains, where the hills reach the height of 90 feet. The bordering hills are in general higher than the interior hills and the hills on the south and east higher than those on the west.

The other portion of the hill land is higher and more irregular. The highest point measured is in the northwest quarter of the northwest quarter of section 3, township 7 south, range 6 west, where the "knobs" rise 240 feet above the mean level of the plain. It is probable that the Centerville knobs, three miles to the north, are higher.

Pigeon Plain is naturally divided into two parts by a terrace (Fig. 1) about 15 feet high, which begins near the point where Lake Plain joins Pigeon Plain and extends in a general northwesterly direction past Midway to Little Pigeon Creek. The plain north of this line is about 15 feet higher than the portion south. The soil to the south is the same as that which covers the river bottoms; that to the north is entirely different, being a sort of reddish clay in some parts of the region and a very black peaty soil in others. This black portion is locally known as "black land." Other differences between the northern and southern parts of Pigeon Plain will be mentioned later.

All the hills on the border of the triangular hill land, the hills along the southern boundry of the northern hill land from Grandview as far as the point where Lake and Pigeon plains meet, and the hills from that point to Little Pigeon Creek, along the line of the terrace, are covered with typical river bluff loess.

The region in the interior of all the triangular hill land and for a short distance north of the southern boundary of the northern hill land is covered with typical interstream loess.

In all the plain region bounded by the loess-capped hills; that is, all the River Plain, Lake Plain and that portion of Pigeon Plain south of the terrace, except a narrow strip in a few places along the base of the hills, wells reveal a great trench filled with an irregular series of clays and water-bearing sands and gravels. This is the region of the driven wells (see map of "Driven Well Area"). In the hill region and most of the region in Pigeon Plain north of the terrace all wells strike rock at comparatively shallow depths.

As the name would imply, in the region of driven wells all wells are driven. This method of sinking wells makes accurate well sections hard to obtain. The only thing that can be obtained accurately is the depth or depths of the water-bearing strata and in a general way something of what was passed through before water was found. Only a few open wells are found in this region, and they were dug so long ago that less can be learned from them than from the driven wells.

The depth of the driven wells varies considerably, in one place a difference of 10 feet having been noticed betwen two wells on level ground not 40 feet apart. The deepest wells found are near Rockport. One is 70, the other 65 feet. Neither struck rock. The normal depth of wells in middle Lake Plain and Northern Pigeon Plain south of the terrace range from 17 to 40 feet. Very few wells are deeper. One well, 56 feet deep, in the narrowest part of Lake Plain, did not strike rock. In River Plain they range from 30 to 60 feet.

From these wells we learn something of the original depth of this filled valley. If all these sands and gravels, which underlie Lake, River and a portion of Pigeon Plain could be removed, a valley extending at least 56 feet and probably more than 70 feet below the present plain level, and having its sides of middle carboniferous formation, would be revealed. (See Fig. 2.)

This valley is the same depth as the half-filled Ohio gorge, of which it is a continuation. It is filled with the same materials. The hills on each side are covered with typical river bluff loess in the same manner as those on the erosion scarp of the Ohio. The levels of the Plains are so nearly the same that a portion of the waters of the flood of 1884 rushed through the Lake Plain, and entering Pigeon Plain, one part followed the terrace and then turned southward to meet the other part and join the waters of the Ohio again where Pigeon and River Plains meet. This stream was four feet deep, and flowed with such swiftness along the base of the bluff where Pigeon and Lake Plains meet that a man could not have stood upright in it.

All these facts lead to the conclusion that the Ohio River at one time flowed through Lake Plain and down through Pigeon Plain, entering the

Ohio Valley again between Enterprise and the eastern part of Warrick County.

To the erosive power of the river is to be attributed the greater part, if not the whole, of the valley now occupied by Lake Plain. In Pigeon Plain the work done was simply the deepening, and it may be a little broadening, on the eastern side of a broad valley, extending from the northeast, which the river entered after cutting through the rock in Lake Plain. A portion of this more ancient valley extending from the northeast still remains intact north of the terrace. The terrace being simply the northern boundary of the Ohio's down cutting in the more ancient valley.

The work done in cutting out the Lake Plain valley through solid sandstone, limestone and shale is probably just about equal to the deepening of the more ancient Pigeon Plain. This would explain in great part at least the conspicuous difference in width which exists between various parts of the old river cut-off.

Nearly all the swampy area mentioned above, that is the lands drained by Swan Pond, Lake Drain, Lake, Sweezer's Cow Pond, and Hoop-pole ditches are simply portions of the old channel which have been but imperfectly filled. They are in some respects similar to the half-filled old river cut-offs and marshes of the lower Mississippi, but differ in that the cut-offs of the Mississippi are made through soft, yielding alluvium, while this one has been made, in part at least, through solid rock.

The ancient stream plains which the Ohio entered after cutting through the hills two miles east of Richland is locally called Pigeon Valley, but as has been intimated before, is not at present occupied by Little Pigeon Creek. A cross section (see Fig. 3) of the country running southeastward along a line drawn from a quarter east of the middle of section 35, township 5 south, range 7 west, to a quarter south of the middle of section 6, town 6 south, range 6 west, shows Little Pigeon Creek in a young, narrow, V-shaped, rock-bound valley separated by a hill of sandstone thirty (30) feet high from the broad flat alluvial-filled valley east of it. Well sections in this valley reveal in a few places a depresson 60 feet deep filled with blue sand.

Near the base of the hills, bounding the River Plain, north of Enterprise is a series of gravels and sands which are of considerable value in determining the age of the old Ohio cut-off. The gravels rise 40 feet in the hills near the junction of River and Pigeon Plains, but after the hills along the eastern part of Pigeon Plain are reached they are nowhere to be found. Evidently where these gravels were deposited no considerable breach existed in the line of hills from the extreme southwestern point of the triangular hill-land to Warrick county. The Ohio River therefore flowed through Pigeon Plain since the deposition of the gravel.

The presence of typical river bluff loess on the sides of the valley shows that it was a valley at the time of the deposition of the loess. This channel was therefore cut between the deposition of the gravel and the loess. According to McGee the loess belongs to the Columbia division of the Pleistocene.* Briefly there are four reasons for referring the gravel to the Tertiary:

1. Absence of glacial pebbles in the deposit.
2. Unconformity and old soil between gravel and loess.
3. Lithological resemblance of bed to known Tertiary beds.
4. Erosion record furnished by old river channel.

If the gravels are Tertiary they must belong to the Lafayette division of the Neocene, for they resemble no other Tertiary formation.

These facts seem to establish the age of the old river channel. Since it seems probable that Lafayette sands and gravels are not found in the old channel, it was cut after the Lafayette time. The loess shows that it existed as a valley during the Columbia period. It was therefore cut during the Post Lafayette and Pre-Columbia High Level, or in other words, in the high level period which preceded the first glacial invasion.

During the "Pre-Lafayette High Level" the land in this region stood just about the same height as now, and thus the Ohio cut or deepened the valley it now occupies. This was followed by the Lafayette low-level, when the ocean covered the eastern plain and a great bay extended up the Mississippi Valley. An arm of this bay extended up the Ohio past Spencer county. During this time the sands and gravels were laid down as an estuarine deposit.

After the deposition of this gravel the land rose probably 100 feet above its Pre-Lafayette level in Spencer County, and the Ohio cut out most of the gravel beds laid down in the Lafayette. It trenched over 70 feet into the underlying Carboniferous rocks, and at some time during this period, for reasons not evident at present, it turned aside and cut out the channel now occupied by Lake Plain and that portion of Pigeon Plain south of the terrace.

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*U. S. Geological Survey, 12th Annual Report, p. 384.

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Proceedings of the Indiana Academy of Science

1898

PROCEEDINGS

OF THE

Indiana Academy of Science

1898.

EDITOR, - - GEO. W. BENTON.

ASSOCIATE EDITORS:

C. A. WALDO, W. A. NOYES,
C. H. EIGENMANN, STANLEY COULTER,
V. F. MARSTERS, THOMAS GRAY,
M. B. THOMAS, JOHN S. WRIGHT.

INDIANAPOLIS, IND.
1899.

INDIANAPOLIS:
Wm. B. Burford, Printer,
1899.

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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.]

Preamble.

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 body, 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,

Publication of the reports of the Indiana Academy of Science.

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.

Editing reports.

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 services, 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

Number of printed reports.

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. Proviso.

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 Indiana 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. Disposition of reports.

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. Emergency.

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

[Approved March 5, 1891.]

SECTION 1. *Be it enacted by the General Assembly of the State of Indiana,* That it shall be unlawful for any person to kill any wild bird other than a game bird, or purchase, offer for sale any such wild bird after it has been killed, or to destroy the nests or the eggs of any wild bird. Birds.

SEC. 2. For the purpose of this act the following shall be considered game birds; the Anatidæ, commonly called swans, geese, brant, and river and sea ducks; the Rallidæ, commonly known as rails, coots, mudhens, and gallinules; the Limicolæ, commonly Game birds.

known as shore birds, plovers, surf birds, snipe, woodcock and sandpipers, tattlers and curlews; the Gallinæ, commonly known as wild turkeys, grouse, prairie chickens, quail, and pheasants, all of which are not intended to be affected by this act.

Penalty. SEC. 3. Any person violating the provisions of Section 1 of this act shall, upon conviction, be fined in a sum not less than ten nor more than fifty dollars, to which may be added imprisonment for not less than five days nor more than thirty days.

Permits. SEC. 4. Sections 1 and 2 of this act shall not apply to any person holding a permit giving the right to take birds or their nests and eggs for scientific purposes, as provided in Section 5 of this act.

Permits to Science. SEC. 5. Permits may be granted by the Executive Board of the Indiana Academy of Science 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 said Board written testimonials from two well-known scientific men certifying to the good character and fitness of said applicant to be entrusted with such privilege and pay to said Board one dollar to defray the necessary expenses attending the granting of such permit, and must file with said Board a Bond. properly executed bond in the sum of two hundred dollars, signed by at least two responsible citizens of the State as sureties. The Bond forfeited. bond shall be forfeited to the State and the permit become void upon proof that the holder of such permit has killed any bird or taken the nests or eggs of any bird for any other purpose than that named in this section and shall further be subject for each offense to the penalties provided in this act.

Two years. SEC. 6. The permits authorized by this act shall be in force for two years only from the date of their issue, and shall not be transferable.

Birds of prey. SEC. 7. The English or European house sparrow (passer domesticus), crows, hawks, and other birds of prey are not included among the birds protected by this act.

Acts repealed. SEC. 8. All acts or parts of acts heretofore passed in conflict with the provisions of this act are hereby repealed.

Emergency. SEC. 9. An emergency is declared to exist for the immediate taking effect of this act, therefore the same shall be in force and effect from and after its passage.

Taking Fish for Scientific Purposes.

Section 2, Chapter XXX, Acts of 1899, page 45, makes the following provision for the taking of fish for scientific purposes: "Provided, That in all cases of scientific observation he [the Commissioner of Fisheries and Game] shall require a permit from the Indiana Academy of Science."

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Vice-President,

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Assistant Secretary,

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Press Secretary,

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A. W. Butler, C. H. Eigenmann, W. S. Blatchley.

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A. W. Butler, J. S. Wright, G. W. Benton.

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1886–7	John M. Coulter	Amos W. Butler			O. P. Jenkins.
1887–8	J. P. D. John	Amos W. Butler			O. P. Jenkins.
1888–9	John C. Branner	Amos W. Butler			O. P. Jenkins.
1889–90	T. C. Mendenhall	Amos W. Butler			O. P. Jenkins.
1890–1	O. P. Hay	Amos W. Butler			O. P. Jenkins.
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1895–6	Stanley Coulter	John S. Wright	A. J. Bigney		W. P. Shannon.
1896–7	Thomas Gray	John S. Wright	A. J. Bigney		W. P. Shannon.
1897–8	C. A. Waldo	John S. Wright	A. J. Bigney	Geo. W. Benton	J. T. Scovell.
1898–9	C. H. Eigenmann	John S. Wright	E. A. Schultze	Geo. W. Benton	J. T. Scovell.

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 programmes 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 specially 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 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 evening 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 news paper 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.

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J. C. Arthur	1893	Lafayette.
P. S. Baker	1893	Greencastle.
George W. Benton	1896	Indianapolis.
A. J. Bigney	1897	Moore's Hill.
A. W. Bitting	1897	Lafayette.
W. S. Blatchley	1893	Indianapolis.
J. C. Branner	1893	Stanford University, Cal.
Wm. Lowe Bryan	1895	Bloomington.
Severance Burrage	1898	Lafayette.
A. W. Butler	1893	Indianapolis.
R. E. Call	1894	Brooklyn, N. Y.
J. L. Campbell	1893	Crawfordsville.
John M. Coulter	1893	Chicago, Ill.
Stanley Coulter	1893	Lafayette.
D. W. Dennis	1895	Richmond.
C. R. Dryer	1897	Terre Haute.
A. Wilmer Duff	1896	Lafayette.
C. H. Eigenmann	1893	Bloomington.
A. L. Foley	1897	Bloomington.
Katherine E. Golden	1895	Lafayette.
W. F. M. Goss	1893	Lafayette.
Thomas Gray	1893	Terre Haute.
A. S. Hathaway	1895	Terre Haute.
O. P. Hay	1893	Washington, D. C.
H. A. Huston	1893	Lafayette.
J. P. D. John	1893	Greencastle.
D. S. Jordan	1893	Stanford University, Cal.
Arthur Kendrick	1898	Terre Haute.
Robert E. Lyons	1896	Bloomington.
V. F. Marsters	1893	Bloomington.

*Date of election.

C. L. Mees	*1894	Terre Haute.
T. C. Mendenhall	1893	Worcester, Mass.
Joseph Moore	1896	Richmond.
D. M. Mottier	1893	Bloomington.
W. A. Noyes	1893	Terre Haute.
L. J. Rettger	1896	Terre Haute.
J. T. Scovell	1894	Terre Haute.
Alex. Smith	1893	Chicago, Ill.
Moses C. Stevens	1898	Lafayette.
W. E. Stone	1893	Lafayette.
Joseph Swain	1898	Bloomington.
M. B. Thomas	1893	Crawfordsville.
L. M. Underwood	1893	New York City.
†T. C. Van Nuys	1893	Bloomington.
C. A. Waldo	1893	Lafayette.
F. M. Webster	1894	Wooster, O.
H. W. Wiley	1895	Washington, D. C.
John S. Wright	1894	Indianapolis.

NON-RESIDENT MEMBERS.

D. H. Campbell	Stanford University, Cal.
B. W. Evermann	Washington, D. C.
Charles H. Gilbert	Stanford University, Cal.
C. W. Green	Stanford University, Cal.
C. W. Hargitt	Syracuse, N. Y.
Edward Hughes	Stockton, Cal.
O. P. Jenkins	Stanford University, Cal.
J. S. Kingsley	Tufts College, Mass.
Alfred Springer	Cincinnati, O.
Robert B. Warder	Washington, D. C.
Ernest Walker	Clemson College, S. C.

ACTIVE MEMBERS.

G. A. Abbott	Evansville.
Frederick W. Andrews	Bloomington.

* Date of election.
† Deceased, August 1, 1898.

Curtis Atkinson	Bloomington.
George H. Ashley	Indianapolis.
Edward Ayres	Lafayette.
Timothy H. Ball	Crown Point.
J. A. Bergstrom	Bloomington.
Alexander Black	Greencastle.
Edwin M. Blake	Lafayette.
Lee F. Bennett	Valparaiso.
Donaldson Bodine	Crawfordsville.
M. C. Bradley	Bloomington.
M. A. Brannon	Grand Forks, N. D.
Fred J. Breeze	Pittsburg.
J. A. Brice	
Frank P. Bronson	Indianapolis.
O. W. Brown	
Charles C. Brown	Bloomington, Ill.
H. L. Bruner	Irvington.
A. Hugh Bryan	Lafaye te.
J. B. Burris	Cloverdale.
Ada C. Campbell	South Bend.
E. J. Chansler	Bicknell.
Fred M. Chamberlain	Bloomington.
Walter W. Chipman	Warsaw.
George Clements	Crawfordsville.
H. J. Clements	Washington.
Charles Clickener	Tangier.
Mel. T. Cook	Greencastle.
U. O. Cox	Mankato, Minn.
Albert B. Crowe	Ft. Wayne.
M. E. Crowell	Indianapolis.
Glenn Culbertson	Hanover.
Will Cumback	Greensburg.
Alida M. Cunningham	Lafayette.
H. S. Cunningham	Indianapolis.
B. M. Davis	Los Angeles, Cal.
Martha Doan	Westfield.
J. P. Dolan	Syracuse.
Hans Duden	Indianapolis.

Joseph Eastman........................Indianapolis.
E. G. Eberhardt........................Indianapolis.
M. N. Elrod........................Columbus.
F. L. Emory........................Morgantown, W. Va.
Percy Norton Evans........................Lafayette.
Samuel G. Evans........................Evansville.
Carlton G. Ferris........................Big Rapids, Mich.
E. M. Fisher........................Urmeyville.
J. R. Francis........................Indianapolis.
Austin Funk........................New Albany.
J. B. Garner........................Crawfordsville.
Robert G. Gillum........................Terre Haute.
Michael J. Golden........................Lafayette.
W. E. Goldsborough........................Lafayette.
S. S. Gorby........................Franklin.
Vernon Gould........................Rochester.
J. C. Gregg........................Brazil.
Alden H. Hadley........................Melbourne, Fla.
U. S. Hanna........................Bloomington.
Chas. A. Helvie........................Chicago.
Flora Herr........................Bloomington.
Robert Hessler........................Indianapolis.
J. A. Hill........................
Frank C. Higgins........................Terre Haute.
Lucius M. Hubbard........................South Bend.
Alex. Johnson........................Ft. Wayne.
W. B. Johnson........................Franklin.
Chancey Juday........................Bloomington.
William J. Karslake........................Irvington.
D. S. Kelley........................Jeffersonville.
O. L. Kelso........................Terre Haute.
A. M. Kenyon........................Lafayette.
E. M. Kindle........................Bloomington.
Ernest I. Kizer........................South Bend.
Charles T. Knipp........................Bloomington.
Thomas Large........................Evansville.
John Levering........................Lafayette.
V. H. Lockwood........................Indianapolis.

William A. Macbeth .... Terre Haute.
Cora March .... Lawrenceburg.
Robert Wesley McBride .... Indianapolis.
Rousseau McClellan .... Indianapolis.
D. T. McDougal .... Minneapolis, Minn.
G. W. Martin .... Indianapolis.
Julius B. Meyer .... Lafayette.
O. M. Meyncke .... Brookville.
Franklin S. Miller .... Brockville.
John A. Miller .... Bloomington.
W. J. Moenkhaus .... San Paulo, Brazil.
H. T. Montgomery .... South Bend.
J. P. Naylor .... Greencastle.
Charles E. Newlin .... Irvington.
John F. Newsom .... Stanford University, Cal.
E. W. Olive .... Indianapolis.
D. A. Owen .... Franklin.
Rollo J. Peirce .... Martinsville.
W. H. Peirce .... Chicago, Ill.
Ralph B. Polk .... Greenwood.
James A. Price .... Bloomfield.
Frank A. Preston .... Indianapolis.
A. H. Purdue .... Fayetteville, Ark.
Ryland Ratliff .... Fairmount.
H. G. Reddick .... Bloomington.
Claude Riddle .... Lafayette.
Bessie C. Ridgley .... Chicago, Ill.
D. C. Ridgley .... Chicago, Ill.
Curtis A. Rinson .... Bloomington.
Giles E. Ripley .... Lafayette.
George L. Roberts .... Greensburg.
Adolph Rodgers .... New Castle.
D. A. Rothrock .... Bloomington.
John F. Schnaible .... Lafayette.
C. E. Schafer .... Huntington.
E. A. Schultze .... Ft. Wayne.
Howard Schurmann .... Indianapolis.
John W. Shepherd .... Terre Haute.

Claude Siebenthal	Bloomington.
G. W. Sloan	Indianapolis.
J. R. Slonaker	Bloomington.
Richard A. Smart	Lafayette.
Harold B. Smith	Worcester, Mass.
Theo. W. Smith	Indianapolis.
Lillian Snyder	Lafayette.
F. P. Stauffer	Logansport.
H. M. Stoops	Brookville.
William Stewart	Lafayette.
George A. Talbert	West Superior, Wis.
Frank B. Taylor	Ft. Wayne.
S. N. Taylor	West Lafayette.
Erastus Test	Lafayette.
F. C. Test	Chicago, Ill.
J. F. Thompson	Richmond.
A. L. Treadwell	Oxford, Ohio.
Daniel J. Troyer	Goshen.
W. P. Turner	Lafayette.
A. B. Ulrey	North Manchester.
W. B. Van Gorder	Knightstown.
Arthur C. Veatch	Rockport.
H. S. Voorhees	Brookville.
J. H. Voris	Huntington.
F. A. Walker	Anderson.
Fred C. Whitcomb	Delphi.
William M. Whitten	South Bend.
Mae Woldt	Irvington.
W. L. Wood	Covington.
William Watson Woollen	Indianapolis.
A. J. Woolman	Duluth, Minn.
J. F. Woolsey	Indianapolis.
A. C. Yoder	Vincennes.
O. B. Zell	Clinton.

Fellows	49
Non-resident members	11
Active members	141
Total	201
Deaths	2

In Memoriam.

JOSEPH W. MARSEE,

Died, Indianapolis, December Third, 1898.

In Memoriam.

THOMAS C. VAN NUYS,

Died, Charlotteville, Virginia, August First, 1898.

LIST OF FOREIGN CORRESPONDENTS.

AFRICA.

Dr. J. Medley Wood, Natal Botanical Gardens, Berea Durban, South Africa.

South African Philosophical Society, Cape Town, South Africa.

ASIA.

China Branch Royal Asiatic Society, Shanghai, China.

Asiatic Society of Bengal, Calcutta, India.

Geological Survey of India, Calcutta, India.

Indian Museum of India, Calcutta, India.

India Survey Department of India, Calcutta, India.

Deutsche Gesellschaft für Natur-und Völkerkunde Ostasiens, Tokio, Japan.

Imperial University, Tokio, Japan.

Koninklijke Naturkundige Vereeniging in Nederlandsch-Indie, Batavia, Java.

Hon. D. D. Baldwin, Honolulu, Hawaiian Islands.

EUROPE.

V. R. Tschusizu Schmidhoffen, Villa Tannenhof, Halle in Salzburg, Austria.

Herman von Vilas, Innsbruck, Austria.

Ethnologische Mittheilungen aus Ungarn, Budapest, Austro-Hungary.

Mathematische und Naturwissenschaftliche Berichte aus Ungarn, Budapest, Austro-Hungary.

K. K. Geologische Reichsanstalt, Vienna (Wien), Austro-Hungary.

K. U. Naturwissenschaftliche Gesellschaft, Budapest, Austro-Hungary.

Naturwissenschaftlich-Medizinischer Verein in Innsbruck (Tyrol), Austro-Hungary.

Editors "Termeszetrajzi Fuzetk," Hungarian National Museum, Budapest, Austro-Hungary.

Dr. Eugen Dadai, Adj. am Nat. Mus., Budapest, Austro-Hungary.

Dr. Julius von Madarasz, Budapest, Austro-Hungary.

K. K. Naturhistorisches Hofmuseum, Vienna (Wien), Austro-Hungary.

Ornithological Society of Vienna (Wien,) Austro-Hungary.

Zoologische-Botanische Gesellschaft in Wien, Wien, Austro-Hungary.

Dr. J. von Csato, Nagy Enyed, Austro-Hungary.

Malacological Society of Belgium, Brussels, Belgium.

Royal Academy of Science, Letters and Fine Arts, Brussels, Belgium.

Royal Linnean Society, Brussels, Belgium.

Societé Belge de Geologie, de Palaeontologie et Hydrologie, Brussels, **Belgium.**

Societé Royale de Botanique, Brussels, Belgium.

Societé Geologique de Belgique, Liège, Belgium.

Prof. Christian Frederick Lutken, Copenhagen, Denmark.

Bristol Naturalists' Society, Bristol, England.

Geological Society of London, London, England.

Linnean Society of London, London, England.

Liverpool Geological Society, Liverpool, England.

Manchester Literary and Philosophical Society, Manchester, England.

"Nature," London, England.

Royal Botanical Society, London, England.

Royal Geological Society of Cornwall, Penzance, England.

Royal Microscopical Society, London, England.

Zoölogical Society, London, England.

Lieut-Col. John Biddulph, 43 Charing Cross, London, England.

Dr. G. A. Boulenger, British Mus. (Nat. Hist.), London, England.

F. DuCane Godman, 10 Chandos St., Cavendish Sq., London, England.

Hon. E. L. Layard, Budleigh Salterton, Devonshire, England.

Mr. Osbert Salvin, Hawksford, Fernshurst, Haslemere, England.

Mr. Howard Saunders, 7 Radnor Place, Hyde Park, London W., England.

Phillip L. Sclater, 3 Hanover Sq., London W., England.

Dr. Richard Bowlder Sharpe, British Mus. (Nat. His.), London, England.
Prof. Alfred Russell Wallace, Corfe View, Parkstone, Dorset, England.

Botanical Society of France, Paris, France.
Ministèrie de l'Agriculture, Paris, France.
Societé Entomologique de France, Paris, France.
L'Institut Grand Ducal de Luxembourg, Luxembourg, Lux., France.
Soc. de Horticulture et de Botan. de Marseille, Marseilles, France.
Societé Linneenne de Bordeaux, Bordeaux, France.
La Soc. Linneenne de Normandie, Caen, France.
Soc. des Naturelles, etc., Nantes, France.
Zoölogical Society of France, Paris, France.
Baron Louis d' Hamonville, Meurthe et Moselle, France.
Prof. Alphonse Milne-Edwards, Rue Cuvier, 57, Paris, France.

Botanischer Verein der Provinz Brandenburg, Berlin, Germany.
Deutsche Geologische Gesellschaft, Berlin, Germany.
Entomologischer Verein in Berlin, Berlin, Germany.
Journal für Ornithologie, Berlin, Germany.
Prof. Dr. Jean Cabanis, Alte Jacob Strasse, 103 A., Berlin, Germany.
Augsburger Naturhistorischer Verein, Augsburg, Germany.
Count Hans von Berlspsen, Münden, Germany.
Braunschweiger Verein für Naturwissenschaft, Braunschweig, Germany.
Bremer Naturwissenschaftlicher Verein, Bremen, Germany.
Kaiserliche Leopoldische-Carolinische Deutsche Akademie der Naturforscher, Halle, Saxony, Germany.
Königlich-Sächsische Gesellschaft der Wissenschaften, Mathematisch-Physische Classe, Leipzig, Saxony, Germany.
Naturhistorische Gesellschaft zu Hannover, Hanover, Prussia, Germany.
Naturwissenschaftlicher Verein in Hamburg, Hamburg, Germany.
Verein für Erdkunde, Leipzig, Germany.
Verein für Naturkunde, Wiesbaden, Prussia.

Belfast Natural History and Philosophical Society, Belfast, Ireland.
Royal Dublin Society, Dublin.

Societa Entomologica Italiana, Florence, Italy.
Prof. H. H. Giglioli, Museum Vertebrate Zoölogy, Florence, Italy.
Dr. Alberto Perugia, Museo Civico di Storia Naturale, Genoa, Italy.
Societa Italiana de Scienze Naturali, Milan, Italy.
Societa Africana d' Italia, Naples, Italy.
Dell 'Academia Pontifico de Nuovi Lincei, Rome, Italy.
Minister of Agriculture, Industry and Commerce, Rome, Italy.
Rassegna della Scienze Geologiche in Italia, Rome, Italy.
R. Comitato Geologico d' Italia, Rome, Italy.
Prof. Count. Tomasso Salvadori, Zoölog. Museum, Turin, Italy.

Royal Norwegian Society of Sciences, Throndhjem, Norway.
Dr. Robert Collett, Kongl. Frederiks Univ., Christiana, Norway.

Academia Real des Sciencias de Lisboa (Lisbon), Portugal.

Comité Geologique de Russie, St. Petersburg, Russia.
Imperial Academy of Sciences, St. Petersburg, Russia.
Imperial Society of Naturalists, Moscow, Russia.

The Botanical Society of Edinburg, Edinburg, Scotland.
John J. Dalgleish, Brankston Grange, Bogside Sta., Sterling, Scotland.
Edinburgh Geological Society, Edinburgh, Scotland.
Geological Society of Glasgow, Scotland.
John A. Harvie-Brown, Duniplace House, Larbert, Stirlingshire, Scotland.
Natural History Society, Glasgow, Scotland.
Philosophical Society of Glasgow, Glasgow, Scotland.
Royal Society of Edinburgh, Edinburgh, Scotland.
Royal Physical Society, Edinburgh. Scotland.

Barcelona Academia de Ciencias y Artes, Barcelona, Spain.
Royal Academy of Sciences, Madrid, Spain.

Institut Royal Geologique de Suède, Stockholm, Sweden.
Societé Entomologique à Stockholm, Stockholm, Sweden.
Royal Swedish Academy of Science, Stockholm, Sweden.

Naturforschende Gesellschaft, Basel, Switzerland.

Naturforschende Gesellschaft in Berne, Berne, Switzerland.

La Societé Botanique Suisse, Geneva, Switzerland.

Societé Helvetique de Sciences Naturelles, Geneva, Switzerland.

Societé de Physique et d' Historie Naturelle de Geneva, Geneva, Switzerland.

Concilium Bibliographicum, Zürich-Oberstrasse, Switzerland.

Naturforschende Gesellschaft, Zürich, Switzerland.

Schweizerische Botanische Gesellschaft, Zürich, Switzerland.

Prof. Herbert H. Field, Zürich, Switzerland.

AUSTRALIA.

Linnean Society of New South Wales, Sidney, New South Wales.

Royal Society of New South Wales, Sidney, New South Wales.

Prof. Liveridge, F. R. S., Sidney, New South Wales.

Hon. Minister of Mines, Sidney, New South Wales.

Mr. E. P. Ramsey, Sidney, New South Wales.

Royal Society of Queensland, Brisbane, Queensland.

Royal Society of South Australia, Adelaide, South Australia.

Victoria Pub. Library, Museum and Nat. Gallery, Melbourne, Victoria.

Prof. W. L. Buller, Wellington, New Zealand.

NORTH AMERICA.

Natural Hist. Society of British Columbia, Victoria, British Columbia.

Canadian Record of Science, Montreal, Canada.

McGill University, Montreal, Canada.

Natural Society, Montreal, Canada.

Natural History Society, St. Johns, New Brunswick.

Nova Scotia Institute of Science, Halifax, N. S.

Manitoba Historical and Scientific Society, Winnepeg, Manitoba.

Dr. T. McIlwraith, Cairnbrae, Hamilton, Ontario.

The Royal Society of Canada, Ottawa, Ontario.

Natural History Society, Toronto, Ontario.

Hamilton Association Library, Hamilton, Ontario.

Canadian Entomologist, Ottawa, Ontario.

Department of Marine and Fisheries, Ottawa, Ontario.

Ontario Agricultural College, Guelph, Ontario.

Canadian Institute, Toronto.

Ottawa Field Naturalists' Club, Ottawa, Ontario.

University of Toronto, Toronto.

Geological Survey of Canada, Ottawa, Ontario.

La Naturaliste Canadian, Chicontini, Quebec.

La Naturale Za, City of Mexico.

Mexican Society of Natural History, City of Mexico.

Museo Nacional, City of Mexico.

Sociedad Cientifica Antonio Alzate, City of Mexico.

Sociedad Mexicana de Geographia y Estadistica de la Republica Mexicana, City of Mexico.

WEST INDIES.

Victoria Institute, Trinidad, British West Indies.

Museo Nacional, San Jose, Costa Rica, Central America.

Dr. Anastasia Alfaro, Secy. National Museum, San Jose, Costa Rica.

Rafael Arango, Havana, Cuba.

Jamaica Institute, Kingston, Jamaica, West Indies.

SOUTH AMERICA.

Argentina Historia Natural Florentine Amegline, Buenos Ayres, Argentine Republic.

Musée de la Plata, Argentine Republic.

Nacional Academia des Ciencias, Cordoba, Argentine Republic.

Sociedad Cientifica Argentina, Buenos Ayres.

Museo Nacional, Rio de Janeiro, Brazil.

Sociedad de Geographia, Rio de Janeiro, Brazil.

Dr. Herman von Jhering, Dir. Zoöl. Sec. Con. Geog. e Geol. de Sao Paulo, Rio Grande do Sul, Brazil.

Deutscher Wissenschaftlicher Verein in Santiago, Santiago, Chili.

Societé Scientifique du Chili, Santiago, Chili.

Sociedad Guatemalteca de Ciencias, Guatemala, Guatemala.

. . . PROGRAM . . .

OF THE

FOURTEENTH ANNUAL MEETING

OF THE

Indiana Academy of Science,

STATE HOUSE, INDIANAPOLIS,

December 28, 29 and 30, 1898.

OFFICERS AND EX-OFFICIO EXECUTIVE COMMITTEE.

C. A. WALDO, President, C. H. EIGENMANN, Vice-President, JOHN S. WRIGHT, Secretary.
A. J. BIGNEY, Asst. Secretary, G. W. BENTON, Press Secretary.
J. T. SCOVELL, Treasurer.

THOMAS GRAY,	W. A. NOYES,	O. P. HAY,	J. P. D. JOHN,
STANLEY COULTER,	J. C. ARTHUR,	T. C. MENDENHALL,	JOHN M. COULTER,
AMOS W. BUTLER,	J. L. CAMPBELL,	JOHN C. BRANNER,	DAVID STARR JORDAN.

The sessions of the Academy will be held in the State House, in the rooms of the State Board of Agriculture.

Headquarters will be at the Bates House. A rate of $2.00 and up per day will be made to all persons who make it known at the time of registering that they are members of the Academy.

Reduced railroad rates for the members can not be obtained under the present rulings of the Traffic Association. Many of the colleges can secure special rates on the various roads. Those who can not do this, could join the State Teachers' Association and thus secure the one and one-third round trip fare accorded to them.

D. W. DENNIS,
A. J. BIGNEY,
Committee,

GENERAL PROGRAM.

WEDNESDAY, DECEMBER 28.

Meeting of Executive Committee at the Hotel Headquarters .... 8 p. m.

THURSDAY, DECEMBER 29.

General Session .... 9 a. m. to 12 m.
Sectional Meetings .... 2 p. m. to 5 p. m.
Address by President C. A. Waldo .... 7 p. m.

FRIDAY, DECEMBER 30.

General Session, followed by Sectional Meetings .... 9 a. m. to 12 m.
General Session .... 2 p. m. to 4 p. m.

LIST OF PAPERS TO BE READ.

ADDRESS BY THE RETIRING PRESIDENT,

PROFESSOR C. A. WALDO,

At 7 o'clock Thursday evening.

Subject: "The Services of Mathematics."

The address has been placed at this early hour in order that other engagements for the usual hours of evening entertainment may not keep the members of the Academy and their friends from being present.

The following papers will be read in the order in which they appear on the program except that certain papers will be presented "*pari passu*" in sectional meetings. When a paper is called and the reader is not present, it will be dropped to the end of the list, unless by mutual agreement an exchange can be made with another whose time is approximately the same. Where no time was sent with the papers, they have been uniformly assigned ten minutes. Opportunity will be given after the reading of each paper for a brief discussion.

N. B.—By the order of the Academy, no paper can be read until an abstract of its contents or the written paper has been placed in the hands of the Secretary.

GENERAL SUBJECTS.

1. Woollen's Garden of Birds and Botany, 10 m........W. W. Woollen.
2. Plans for the New Buildings of the Biological Station, 10 m.
C. H. Eigenmann and A. C. Yoder.
3. Explorations in the Caves of Missouri and Kentucky, 15 m.
C. H. Eigenmann.
4. Notes on Indigestible Structures in Articles of a Vegetable Diet, 5 m....................................John S. Wright.
5. The Action of Mercury and Amalgams on Aluminum, 10 m.
G. W. Benton.
6. Field Experiments with Formalin, 8 m............M. B. Thomas.
7. Resistance of Cereal Smuts to Formalin and Hot Water, 15 m.
Wm. Stuart.

*8. The Cell Lineage of Podarke, with considerations on Cleavage in general, 10 m..............................A. L. Treadwell.

9. Lake Maxinkuckee, 10 m...............................J. T. Scovell.

10. An Elevated Beach and Recent Costal Plain, near Portland, Maine, 10 m.................................Wm. A. McBeth.
11. Wasted Energy, 10 m.................................J. L. Campbell.
12. A Vesuvian Cycle, 10 m.................................C. A. Waldo.
13. X Ray Transparency, 10 m.................................Arthur L. Foley.
14. The Trouble with Indiana Roads, illustrated with lantern slides, 20 m.................................D. B. Luten.

MATHEMATICAL AND PHYSICAL SUBJECTS.

15. Some Tests on Ball Bearings, 15 m.................................M. J. Golden.
16. Further Studies in the Propagation of Sound, 20 m..A. Wilmer Duff.
17. The Intensity of Telephonic Sounds, 5 m...........A. Wilmer Duff.
18. The Distance to which Small Disturbances Agitate a Liquid, 15 m.................................A. Wilmer Duff.
*19. A Case of Diamond Fluorescence, 5 m.................A. L. Foley.
20. The Evaporation of Water Covered with a Film of Oil, 10 m. A. Wilmer Duff.
21. A Note on Temperature Co-efficient of Electrical Conductivity of Electrolytes, 10 m.................................Arthur Kendrick.
*22. X Rays in Surgery, 10 m.................................A. L. Foley.
23. A Common Text-book Error in the Theory of Envelopes, 10 m. Arthur S. Hathaway.
24. A New Triangle and some of its Properties, 10 m........R. J. Aley.
25. Note on Angel's Method of Inscribing Regular Polygons, 8 m., R. J. Aley.
26. Concurrent Sets of Three Lines Connected with the Triangle. 20 m.................................R. J. Aley.
27. Note on "Note on Smith's Definition of Multiplication," 1 m., A. L. Baker.
28. The Geometry of Simson's Line, 25 m.................C. E. Smith.
29. A Bibliography of Foundations of Geometry, 5 m....M. C. Bradley.
30. Point Invariants for the Lie Groups of the Plane, 10 m. D. A. Rothrock.
31. Differential Invariants Derived from Point Invariants, 10 m., D. A. Rothrock.
32. Mathematical Definitions, 10 m.................Moses C. Stevens.

33. Performance of the Twenty-Million-Gallon Snow Pumping Engine of the Indianapolis Water Company, 5 m......W. F. M. Goss.
34. Tests to Determine the Efficiency of Locomotive Boiler Coverings, 5 m..W. F. M. Goss.
35. The Leonids of 1898, 5 m..........................John A. Miller.
36. A Linear Relation between Certain of Klein's X Functions and Sigma Functions of Lower Stufe, 10 m............John A. Miller.
37. A Formula for the Deflection of Car Bolsters, 10 m....W. K. Hatt.

CHEMICAL SUBJECTS.

38. Camphoric Acid: Reduction of the Neighboring Xylic Acid, 15 m..W. A. Noyes.
39. Alpha hydroxy-dihydro-ciscampholitic Acid, 10 m. W. A. Noyes and J. W. Shepherd.
40. Iodine Absorption of Linseed Oil, 5 m...P. N. Evans and J. O. Meyer.

BOTANICAL SUBJECTS.

41. Some Desmids of Crawfordsville, 10 m..............M. B. Thomas.
42. Karyokinesis in the Embryo-sac, with special reference to the behavior of the Chromatin, 10 m....................D. M. Mottier.
43. Nuclear Division in Vegetative Cells, 10 m...........D. M. Mottier.
44. The Centrosome in Dictyola, 5 m...................D. M. Mottier.
45. The Centrosome in Cells of the Gametophyte of Marchantia, 5 m...D. M. Mottier.
46. Endosperm Haustoria in Lillium Candidum, 5 m......D. M. Mottier.
47. The Effect of Centrifugal Force upon the Cell, 10 m..D. M. Mottier.
48. Absorption of Water by Decorticated Stems, 15 m...Giles E. Ripley.
49. Indiana Plant Rusts, Listed in Accordance with Latest Nomenclature, 10 m...................................J. C. Arthur.
50. The Uredineae of Madison and Noble Counties, with additional Specimens from Tippecanoe County, 10 m..........Lillian Snyder.
51. Aspergyllus oryzæ (Ahlburg) Cohn, 20 m......Katherine E. Golden.
52. A Red Mould, 10 m.........................Ralph Gibson Curtis.
53. The Affinities of the Mycetozoa, 8 m..............Edgar W. Olive.

54. The Morphological Character of the Scales of Cuscuta, 10 m. Alida M. Cunningham.

55. Geographical Distribution of the Species of Cuscuta in North America, 10 m. . . . . .Alida M. Cunningham.

56. Notes on the Germination of Seedlings of Certain Native Plants, 10 m. . . . . .Stanley Coulter.

*57. Re-forestration Possibilities in Indiana, 10 m. . . . . . .Stanley Coulter.

ZOOLOGICAL SUBJECTS.

58. Formalin as a Reagent in Blood Studies, 5 m. . . . . . .Ernest I. Kizer.

59. Species of Diptera, reared in Indiana during the years 1884-1890, 10 m. . . . . .F. M. Webster.

60. Distribution of Broods XXII, V and VII, of Cicada Septendecim, in Indiana, 10 m. . . . . .F. M. Webster.

61. Some Insects belonging to the Genus Isosoma, reared or captured in Indiana, 10 m. . . . . .F. M. Webster.

62. Lake County Crow Roosts, 10 m. . . . . .T. H. Ball.

63. The Distribution of Blood Sinuses in the Reptilian Head, 15 m., H. L. Bruner.

64. On the Regulation of the Supply of Blood to the Venous Sinuses of the Head of Reptiles, with Description of a New Sphincter Muscle on the Jugular Vein, 15 m. . . . . .H. L. Bruner.

65. Note on the Aberrant Follicles in the Ovary of Cymatogaster, 10 m. . . . . .George L. Mitchell.

66. Material for the Study of the Variation of Pimephales notatus (Rafinesque), in Turkey Lake and in Shoe and Tippecanoe Lakes, 10 m. . . . . .J. H. Voris.

67. Preliminary Note upon the Arrangement of Rods and Cones in the Retina of Fishes, 5 m. . . .C. H. Eigenmann and G. H. Hausell.

68. Degeneration in the Eyes of the Amblyopsidæ, its Plan, Process and Causes, 30 m. . . . . .C. H. Eigenmann.

69. The Ear and Hearing of the Amblyopsidæ, 10 m. C. H. Eigenmann and A. C. Yoder.

70. A Case of Convergence, 15 m. .C. H. Eigenmann.

71. Chologaster agassizii and its Eyes, 5 m. . . . . .C. H. Eigenmann.

72. The Eye of Typhlomolge, from the Artesian Wells of San Marcos, Texas, 10 m. . . . . .C. H. Eigenmann.

73. The Eyes of Typhlotriton Spelaeus, 10 m.
C. H. Eigenmann and W. A. Denny.

74. The Blind Rat of Mammoth Cave, 10 m.
C. H. Eigenmann and James R. Slonaker.

*75. Remarks on Birds New to the State Fauna, 10 m. . . . . .A. W. Butler.

76. A Nematoid Worm in an Egg, 5 m. . . . . .Dan J. Troyer.

GEOLOGICAL SUBJECTS.

77. The Geologic Relation of some St. Louis Group Caves and Sinkholes, 10 m. . . . . .Moses N. Elrod.

78. Jug Rock, 5 m. . . . . .Chas. R. Dryer.

†79. The St. Joseph and the Kankakee at South Bend, 10 m.
Chas. R. Dryer.

80. The Meanders of the Muskatatuck at Vernon, Indiana, 5 m.,
Chas. R. Dryer.

81. Old Vernon: A Geographical Blunder, 5 m. . . . . .Chas. R. Dryer.

82. Terraces of the Lower Wabash, 10 m. . . . . .J. T. Scovell.

83. The Kankakee Valley, 10 m. . . . . .H. T. Montgomery.

84. Notes on the Eastern Escarpment of the Knobstone Formation in Indiana, 10 m. . . . . .L. F. Bennett.

*85. A Preglacial Channel on the Falls of Ohio, 3 m. . . .C. E. Siebenthal.

*86. Notes on the Pleistocene Geology of Monroe, Owen and Greene Counties, 10 m. . . . . .C. E. Siebenthal.

87. An Old Shore Line, 5 m. . . . . .D. W. Dennis.

88. Two Cases of Variation of Species with Horizon, 5 m. .D. W. Dennis.

89. Notes on the distribution of the Knobstone Group in Indiana, 10 m. . . . . .J. F. Newsom and J. A. Price.

‡Some Indiana Mildews. . . . . .M. A. Brannon.

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* Author absent. Paper not presented.

† Presented as a part of No. 83.

‡ Paper read at the December meeting, 1889. Not hitherto published; included in this report as a valuable contribution to the State Biological Survey.

FOURTEENTH ANNUAL MEETING OF THE INDIANA ACADEMY OF SCIENCE.

The fourteenth annual meeting of the Indiana Academy of Science was held in Indianapolis, Thursday and Friday, December 29 and 30, 1898, preceded by a session of the Executive Committee of the Academy, 9 p. m., Wednesday, December 28.

At 9 a. m., December 29, President C. A. Waldo called the Academy to order in general session, at which committees were appointed and other routine and miscellaneous business transacted. After the disposition of these affairs, the reading and discussion of papers of the printed program, under the title "General Subjects," occupied the time until adjournment, at 12 m.

The Academy met at 2 p. m. in two sections—biological and physico-chemical—for the reading and discussion of papers. President Waldo presided over the physico-chemical, while J. C. Arthur acted as chairman for the biological section. At 5 p. m. the section meetings adjourned, to meet in general session of the Academy at 7 p. m.

The Executive Committee met at 5:30 p. m., holding a brief session.

Academy met at 7 p. m. Following the disposition of committee reports and other business, the retiring president, Dr. C. A. Waldo, addressed the Academy, first briefly reviewing the progress of scientific work in the State, following with the formal address; subject, "The Services of Mathematics."

Friday, December 30, 9 a. m., the Academy met in general session, with President Waldo in the chair. Following the transaction of business, unread papers were heard and discussed until adjournment, which occurred at 12:15 p. m.

THE FIELD MEETING OF 1898.

The Field Meeting of 1898 was held at Bloomington, Thursday, Friday and Saturday, April 28, 29 and 30.

At 8 p. m. the executive committee met for the transaction of business, after which all visiting members were tendered an informal reception by the local members.

Friday, the 29th, was spent in the field. Leaving Bloomington early in the morning, the party went by rail to Mitchell; from this point it was conveyed by carriage several miles east into a district characterized by caves, subterranean streams and other natural features of much interest.

In the evening, following the return to Bloomington, the Academy was given a reception by the faculty of the Indiana University.

On Saturday, the 30th, members of the Academy made short field excursions in the neighborhood of Bloomington. The success of the meeting was largely due to the efforts of the resident members, who provided means of transportation in the field and spared no pains to make the visit to Bloomington enjoyable.

PRESIDENT'S ADDRESS.

By C. A. Waldo.

INTRODUCTION.

Of the seven volumes of Proceedings published by the Academy or under its direction, it has been my fortune to be more or less intimately connected with the editorial work upon six of them. The general work of the Academy has, therefore, come under my notice in a peculiar way. This fact has led me to attempt a slight departure from the excellent models set by my able predecessors, and to premise the usual discussion expected at this time by a brief resumé of the scientific work recently done in the State, especially during the year 1898.

We may congratulate Indiana upon the amount, the character and the importance of the scientific activity within her borders. In attempting to select a few things for mention we must beforehand pray indulgence. Pardon is asked for sins of omission and commission—these will be because of ignorance or imperfect vision, and for no other reason.

In the following mention, the order of our program for this year is followed.

The mathematicians of the State are showing a commendable zeal in the prosecution of pure and applied mathematics in the higher ranges of the subject, and are building up several centers in which the work done is incomparably beyond that of a generation ago.

Our physicists have been busy investigating electrical, optical and acoustic phenomena and extending our knowledge of these subjects. The year has seen completed within the State a great car-testing plant, the invention of an integrating dynamometer, the completion of investigations on train resistance on straight and curved tracks, and large contributions to engineering literature. Two of our engineering instructors have been honored with important assignments on committees of international importance.

Our chemists have been establishing the value of our coal deposits, have enlarged our knowledge of toxicology, have made special examination of alkaloids and have contributed towards the investigation of food supplies, the exhaustion and restoration of soils.

The year has witnessed, with the co-operation of the Academy, the completion of a treatise on the Phanerogamic Flora of the State, giving the range of nearly 1,500 species, together with specific studies of forests, weeds, and unutilized vegetable resources; this now is awaiting publication.

The year has also seen the culmination of extensive investigations upon beet sugar as a possible Indiana product and the determination of large areas—practically the whole of the northern part of the State—where under existing conditions the sugar beet can be cultivated with profit. Plant disease, like the San José scale on fruit trees or smut on cereals, have received much attention, and valuable results have been obtained. Valuable conclusions have been reached in the use of specific fertilizers for specific plants, and upon the relative merits of surface and sub-irrigation.

Yeast investigations have been continued and further conclusions reached of prime importance to every household.

Additions have been made to our knowledge of cell life and cell modification in plants, as affecting various theories of heredity, and much systematic work has been prosecuted in various parts of the State tending to perfect our knowledge of the State flora. Our denuded lands and their possible reforestration have received scientific attention.

In zoölogy the greatest event of the year has been the issuance from the State Geologist's office of a monograph upon the birds of Indiana. This work is thoroughly up to date and is not a mere catalogue. It gives attention to the economic side of bird life, and enables the farmer to recognize his friends and enemies. No recent extensive scientific publication in the State has created such a widespread interest. An edition of 8,000 has been already exhausted and the demand is for more.

An event of almost equal importance is the removal of the Summer Biological Laboratory from Turkey to Eagle Lake. At the former location many Indiana teachers and scientific workers have been trained in laboratory methods; many more will find their way to the new location and through its influence will enter the ranks of trained specialists. In addition to this, much light is being thrown upon the problem of variation as bearing on the origin of species. During the year there must be credited to Indiana some first-class work on cave fauna which is receiving national attention, and which must have a large bearing upon the problem of the influence of environment.

Animal diseases have been investigated with varying degrees of success, and studies made of food for various forms of live stock.

In the geological work of the year in Indiana, the influence of the new scientific spirit abroad in our midst is especially manifest. Besides the report on birds already referred to, we find in the volume for 1897, recently distributed, a timely revision of Indiana paleontology, and further prosecution of county geological surveys. On the economic side, the clay industries have been well and exhaustively set forth, while the conflicting interests of oil and gas production have received able attention. It will be found eventually that the fearless conservation of our gas deposits will have paid a thousandfold the expense to the State of our geological department. It is refreshing, too, and characteristic of the true scientific spirit, to note how the truth and the whole truth is told of our disappearing gas supply. No permanent prosperity founded on deceit and misrepresentation can come to our commonwealth. Rigorous, unadulterated scientific truth is, however, a sure basis for wealth, honor, morality and happiness.

Naturally flowing out of gas belt indications comes the work of this year—a prospectus of which is given in the volume of 1897.

A thorough investigation and report upon the vast coal deposits of the State is at this time especially opportune. As this investigation has already shown deposits equal to all demands upon it for two hundred years to come, the result of the work can only be to establish us in a confident reliance upon the industrial future of Indiana.

This review would not be at all complete without some notices of a general character. In sociological matters the State is making splendid progress. Along this line there is only time to mention the new pathological laboratory at the Hospital for the Insane, the establishment of the Indiana Reformatory at Jeffersonville, leading to the rational treatment of criminals, the introduction of the Bertillon measurements in four of our cities, and the increased activity in our Board of State Charities. Sanitation in our centers of population, in our public schools and homes and public buildings, is receiving great attention. The agitation for pure food will probably soon lead to advanced legislation on this important subject.

Educationally, nothing perhaps has occurred comparable to the widespread influence resulting from the general dissemination throughout the

State of twenty-five nature study leaflets conspicuously adapted to the wants of our great rural population.

In our educational centers we note with pleasure the extension of laboratories, the growth of cabinets and library facilities. Attention is also called to the gratifying fact that recently the office of State Entomologist has been created and worthily filled.

An event of unusual significance to those who have occasion from time to time to consult the scientific publications in the State Library is the fact that during the year '98 the large and growing science accumulations of the Academy of Science and of the Brookville Natural Science Club have been made available to the general public by being placed upon the shelves of the State Library.

Two thoughts are suggested here as a conclusion:

1. Such valuable results as we are now securing in works like the birds and the phanerogams of the State, its clays and coals, have been reached only by the organization of our scientists, and through their increase and their development of ideas and enthusiasm, resulting certainly in a marked degree from the thirteen years' influence of the Academy of Science.

2. The official relation which we sustain to the State has brought the feet of our scientists to the ground and the economic aspects of their studies are being emphasized as never before.

At best this is but an imperfect and rapidly dissolving view of the teeming and multiplying scientific progress within Indiana's borders. A wise choice of topics would perhaps have given the whole time of this address to a review of progress in Indiana since 1885, but I must leave that inspiring theme to some future historian.

To-night, fellow-workers, I greet you and congratulate you upon work worthily done. Fame may not always follow endeavor, but, whether public recognition of work attempted and results accomplished ever comes or not, the true scientist knows that his highest compensation is in the opportunity for service, and he is at peace with his environment.

Services of Mathematics.

Of the twelve gentlemen who have preceded me in addressing the Indiana Academy of Science on occasions similar to the present, three might have interested you with a mathematical topic, but they did not.

One, famous for his vigorous championship of Christian thought, chose a subject in which he used mathematical methods in theological reasoning. The other two, though splendidly equipped in mathematics, preferred to present phases of physics. Our program shows six subdivisions of science, among which mathematics has always held a secure place, but up to the present time no one has had the inclination or the courage to attempt to discuss in a popular manner the oldest science and the one second to none in its services to mankind and in the zeal with which it is to-day cultivated and enlarged. It is, I confess, with misgivings that I break this thirteen years' silence, for the range of the subject has now become so vast that no one person can longer hope for an intimate acquaintance with all of it, and any writer must rely more or less on testimony for many results and their bearings upon progress. And yet when we consider the extent to which the science of mathematics is cultivated among educated people, the large part that it plays in all our lives, are we not justified in an occasional attempt to call attention to prominent facts concerning it as they appear to some of us who have spent fifteen years or more in trying to disseminate its truths?

In the British Association there have been at least three notable presentations of the claims of mathematics by three of its most famous exponents. One of these is little less than an inspired plea for his loved discipline, by one of its prophets; a second shows how higher ranges of the subject have been suggested by other sciences; a third is a classic argument for the unrestricted development of mathematics along systematic lines both for its own sake and for its possible future utility in fields now undreamed of. In the American Association there has been a tendency to make mathematical lectures more technical and therefore less interesting to the general public than in the British. One essayist made a notable attempt to explain modern algebra to the uninitiated, a second spoke upon the evolution of algebra, while a third gave a historical disquisition upon the origin of our methods with imaginaries. A fourth was an exception to these in that he argued for reform in the choice of subjects in college curricula and in the manner of presenting them.

The essential difficulty in discussing a mathematical topic is the fact that this science possesses the most highly developed symbolism and an almost perfect technical language. Both these attributes condense our reasoning to a minimum and make it unintelligible to the uninitiated. In trying to popularize, we are in danger of becoming puerile. Most mathematicians of our time have abandoned the former attempt, and therefore speak a language absolutely without meaning to the average man. Often the use of symbols and technical terms is not even a matter of choice. It is a necessity, for the ideas sought to be conveyed can be expressed in no other language. The mathematician, therefore, often labors on with no understanding or appreciation of his work or its results on the part of the general public. His subject is dumped into the same class with the dead languages. Latin, Greek and mathematics must form an unnatural alliance in a fight for recognition. Too frequently the mathematician is grudgingly given but a tithe of what he claims, and even then he is asked why he should cumber the ground and impede the way to higher and more useful pursuits. Before Latin had a literature, mathematics *was*. Now, when the conviction is rapidly gaining ground and in all progressive institutions being put into practice, that a smattering of Greek and Latin soon forgotten are not essentials in education, mathematics have entered new fields and conquered new territory. Their cultivation has gone forward in the last generation in leaps and bounds, their advance has kept pace with and in a large measure conditioned, both on the material and intellectual side, the tremendous and unexampled progress of civilization in that period.

There are three general aspects in which mathematics can be viewed:

First. As a disciplinary study.
Second. As a cult.
Third. As a tool.

These three general grounds for consuming time and effort in cultivating this science are not mutually exclusive. Their territory frequently overlaps and the determination of the stronger incentive often depends upon the point of view of the individual or his environment.

As a disciplinary study, mathematics are present in some form in all the curricula of colleges, high schools and the grades. In the grades, however, we must recognize as the principal reason for time and effort, the thorough mastery of number and the development through drawing of the form perception for the practical every-day business of life's activities. At this point it has seemed to me that a serious error is quite commonly committed. Too often instructors imbued with that philosophy of education which unduly idealizes every subject taught, make a premature attempt to develop logical processes at the expense of an intimate knowledge of number combinations and of a practical facility in their rapid and accurate manipulation. Very properly in the high school the disciplinary idea predominates, but even here it is a question whether the time is not near at hand when some of the older mathematical subjects taught should be in a measure set aside and other newer ones substituted which are of equal disciplinary value, but whose knowledge content is greater.

In the earlier portion of the college course the disciplinary idea still strongly predominates, but if mathematical study is continued through the last two years and into graduate work it becomes a cult or a profession or a necessary adjunct to a profession.

In its development we may roughly divide mathematics into three general subjects:

Arithmetic.
Geometry.
Algebra.

Yet again these, especially in their higher ranges, continually overlap each other. The theory of numbers seems to belong to arithmetic, yet some of the problems like that of prime numbers, which were among the earliest propounded, demand now for their approximate solution, after twenty-five centuries of development, the highest powers of analysis. In analytics, geometry and algebra melt into each other, while in the modern group theory the three which in their earlier manifestations seem so diverse in spirit and purpose form one grand generalization.

As a discipline these studies need no apology. Their influence in the development of the reasoning powers is unquestioned. They exercise the muscles and sharpen the teeth of the logical faculty. They furnish the growing mind with exercise in useful knowledge with reference to which it can have absolutely no prejudice and, while leading to certain truth, generate confidence in intellectual powers. They develop the inventive faculty by sharpening the powers of comparison, by diversifying and enriching the powers of attack, by developing the power of long continued attention and concentration.

As a cult, pursued for its own sake, it furnishes one of the highest occupations of the intellect. The mind revels in the realm of pure thought, and each triumph must bring the thinker closer to that all-pervading intelligence whose very existence and activity entirely removed from chance and imperfect knowledge must be conditioned by mathematical necessity.

The chemist often pursues his investigations into the constitution of matter without any thought of any possible utility in his results. He pursues the science for the sake of science, that man may grow in knowledge whether or not he can turn that knowledge to practical account in the manufacture of steel or the dyeing of silk or the synthesis of nitrogenous compounds.

Yet not seldom in his case, as in the history of pure mathematics, has it transpired that a truth sought for truth's sake has become the necessary foundation for splendid material achievement. One need but recall the labors of an Archimedes or a Newton to note how a searcher for higher mathematical truth for its own sake may become an epoch-maker in human progress.

It is not my purpose, however, to dwell upon this part of my subject, and I conclude with two quotations from Sylvester. In recommending the high living of the mathematician and nature's provision for his evolution he says: "The mathematician lives long and lives young; the wings of his soul do not early drop off, nor do his pores become clogged with the earthy particles blown from the dusty highways of vulgar life." And again: "Space is the Grand Continuum from which, as from an inexhaustible reservoir, all the fertilizing ideas of modern analysis are derived, and as Brindley, the engineer, once allowed before a parliamentary committee that, in his opinion, rivers were made to feed navigable canals, I feel almost tempted to say that one principal reason for the existence of space, or at least one principal function which it discharges, is that of feeding mathematical invention."

Passing, then, with this cursory mention, a theme so inspiring and fruitful as the consideration of mathematics from the ground of discipline and culture, let us confine our attention to the question of utility alone. What has mathematics done that it should commend itself to the great, struggling masses of humanity who are busily engaged in adding to the surplus products of the race, who are breaking the virgin sod or swinging the artisan's hammer or directing the world's exchanges? Has mathematics any right to stand with physics, chemistry, botany, zoölogy, geology, whose cultivation has revolutionized civilized life?

Can a science which begins with assumptions never in perfect accord with fact and which ends with conclusions impossible of exact application ever get its feet on the ground sufficiently to secure a leverage for pushing along the car of progress?

In considering the services of mathematics from this purely utilitarian point of view we shall find it convenient to speak of

GEOMETRY AND ANALYSIS.

The American people are unusually intelligent, but is it not true that no more than one per cent. of them ever have any adequate conception of the innumerable ways in which geometry enters into their every-day life?

Houses of all kinds, from the humble cottage to the Manufacturers' Building of the White City, from the backwoods meeting house to the vaulted cathedral, first grow on paper under the magic of geometry. Bridges and everything that rolls over them, shops and every manufactured product that comes out of them, grow into being in the same way.

Only a Michael Angelo can hew out a statue without model or drawing, but Raphael himself must resort to mathematical perspective for depth and sky. Not of Euclid do the towering buildings and the diversified industries of a teeming city attest, so much as they do of the Frenchman Monge, upon whose discoveries and researches are based our systems of industrial drawing now so rapidly and deservedly gaining ground. The time, I believe, is not remote when descriptive geometry in some of its phases will find a more open way into the high school and will insist on recognition whatever else may suffer. The heart of the shop is the draughting room, a room without which the trunk line, the ocean steamship and a thousand and one things necessary to our complex civilization can not exist.

The educational revolt of a generation ago against fossilized methods then widely practiced arose from a conviction that we had outgrown monastic institutions. The training suitable for a state of society where all education was in the hands of the church and all educated men became priests was found to be no longer adequate to the needs of a country which was rapidly developing into the most powerful nation on the earth through the industry, inventive genius and mechanical skill of its people.

The learning of the college was laughed to scorn. Then came science and elective courses, but this was not enough. Technology was transplanted from Russia and Germany. It took quick root and has had a marvelous growth in American soil.

Throughout the world what an expansion! till to-day, through the influence of their technical institutions of all classes, the civilized nations are battling for the industrial supremacy of the earth.

So essential is modern geometry to technology that it is safe to say the latter can not exist without the former. Through geometry the controlling mind translates the creative idea to the willing worker, and what was only a dream of beauty or utility now stands clothed in material form under the eye of the world for its edification, elevation and use. The artist whose masterpieces adorn our walls, first groups his figures as he wishes them to appear, then he calls geometry to his assistance to make them seem to be where he wishes them.

We mistake, however, if we confine the services of geometry to technology. Nature is continually inviting the observant mind to geometric study. The beautiful crystalline forms which abound in the rocks of the globe, in the snow and the ice speak of unity in infinite diversity. Under the microscope the thinnest plate of shapeless rock, the very particles of dust at our feet, tell through shape alone a story of origin and character interesting and valuable alike to the physicist, the geologist, and the chemist. The latter, interested in the ultimate forms of matter, finds suggestions for valuable theories upon atomic forms, and constructs geometric molecules in which a dissimilar position of a characteristic atom will in a measure explain such curiosities in nature as right and left-handed sugar, which, though having different properties, still are made of precisely the same constituents in the same proportions.

Analytic geometry occupies the border land between geometry and the higher analysis. The elements of this subject so far as the construction of loci is concerned are rapidly becoming the possession of the reading public. The variations of temperature, of humidity, of productivity, of commerce, of population, of crime and of the price of wheat, from hour to hour, or from day to day, or from season to season, are immediately expressed to the eye by curves in which portions of time are the horizontal measurements and the various values of the function are the vertical. In science the natural way to express one series of facts dependent on another is through a curve. Passing on from loci, which are so full of meaning and so suggestive of causal relations, it is customary to discuss in detail the circle, the parabola, the ellipse and the hyperbola. The laws of gravity lead to these curves, and they are the fundamental orbits of the bodies of the universe. In terrestrial matters they lie at the basis of the laws governing stresses and strains, the study of optics, the propagation of impulses in homogeneous media, and a thousand practical things. As we rise higher and approach analysis we trace the lines along which stresses are propagated and materialize these in the beautiful iron bridge, with its parts nicely shaped and adjusted to the load it is to carry. Advancing further, our lines become in the strain diagram a veritable graphical calculus, through which we discover the stress with which any load, fixed or moving, strains a structure, and therefore through it find a ready means of designing our creations to resist safely the stresses to which they will be subjected.

But this brings us to the question of analysis—the other side of our subject. I shall not dwell upon algebra as we usually understand that term in high school and elementary college work. I need only speak of it as generalized arithmetic to recall to you how it gathers up the rules of the lower subject and condenses and generalizes them, and how, by introducing the result sought at the beginning of a series of operations, we easily carry to a conclusion logical sequences, otherwise exceedingly difficult to follow, and ascertain whether or not the problem proposed is capable of solution.

It must be confessed, however, that algebra in the ordinary school sense is very largely a discipline, little used in the ordinary affairs of life and finding its principal utility in the studies which lie beyond. Yet to pursue these with ease and success, a knowledge of ordinary algebraic methods and facility in algebraic manipulation, including the analysis of the angle, is a prime requisite. I come now to speak of the higher analysis in the sense in which it is ordinarily applied—that is, the infinitesimal calculus and its developments and allied subjects—the invention of which marks an epoch in human progress second, I believe, to no other scientific event.

It is curious, when we think back over human advancement, that some of the things now most patent to our senses escaped recognition so long. The alchemist stumbled through centuries without learning the nature of air and water. The most puerile ideas regarding the earth's structure prevailed down to the American Revolution and later. And so, while arithmetic, Euclid, Diophantine analysis and trigonometry are highly artificial, calculus brings us back to nature. Space and time were continually thrusting themselves upon the attention of man, motion in the former, rate in the latter, as exemplified by every moving thing and changing substance, and were perpetually inviting attention to an arithmetic that took hold upon continuous number and rate of change. Yet for centuries without result. The method of exhaustions came very near to the invention of the calculus, yet Grecian civilization, with its brilliant record, flourished and died without any knowledge of it. A Scotch professor in Dalhousie University was accustomed to say that with the calculus the Greeks would easily have outstripped us in invention. In depth and clearness of thought, in majesty, beauty and originality of ideas and ideals, in strength and suppleness of limb and delicacy of touch, they were clearly our masters. They could geometrize amazingly, but they had no science of continuous number; therefore modern civilization is passing theirs with giant strides.

When the Reformation occurred in Germany, its spirit was abroad everywhere. Had Luther not come to the leadership at that time, who will say that another champion would not have arisen to espouse the new ideas and stake his life upon their success?

So, in the intellectual progress of the seventeenth century, new notions had permeated the mathematical world. The idea of the dependent and the independent variable had gained such ground that the then new science, analytic geometry, was the necessary result. This new subject lent itself readily to the graphic representation of mathematical interdependence and thus furnished in mathematical form a generalized expression and representation for a thing changing in obedience to law. The rate of change necessarily followed soon after, and isolated cases of its use in determining the tangent to a curve show that it was in the air. Newton and Leibnitz immortalized themselves by noting the mathematical drift, seizing the new methods and constructing from them the new discipline.

Thus man came into possession of an instrument adapted to discover and establish the laws and processes of nature because it is constructed on nature's model. Trees do not increase instantly a foot in height and then rest for a period before the next jump. Rivers are not at one instant a swelling, muddy flood, and at the next a clear, tranquil stream. The Knickerbocker Express does not go by jerks and instantaneous leaps from point to point as it passes over the space between Indianapolis and New York. But everything from external nature to the innermost soul of man connect various times, seasons and conditions by continuous number. The tree, the animal grows, the flood abates, the train progresses, mind matures, life expands, love deepens and broadens.

> "Chance and change are busy ever,
> Man decays and ages move."

God alone changeth not.

But everything we see, all else we can think of, is in a state of flux. The rate of these changes is matter of common observation and comment, and it is nothing but the first differential coefficient. Tait says every one uses the ideas of the calculus if he is not a fool. I doubt whether any of us, without we consciously give ourselves to reflection upon the subject, begin to see the clearness, the depth, the breadth, the comprehensiveness, of Newton's philosophic vision when he gave to the world the words *fluent* and *fluxion* in connection with his new culture.

As calculus was the first master-word spoken to the very soul of nature, so it has wrested from her first this secret then that, until man with this powerful ally is rapidly enslaving all her powers to work out his own will.

The calculus rewarded its discoverer by giving him the demonstration of the invisible chains binding the moon to the earth and then by delivering into his hand the secret of the system of the world. Who will estimate the services to civilization of these cosmical studies? Old superstitions disappeared forever. A man's horoscope became only a poetic fancy. Men no longer prayed to be delivered from the flesh, the devil and the comet. But our solar system was reduced to order and beauty, while mathematical analysis reached out with her long, delicate, quivering fingers and snatched from the depths of space a new planet—never seen by the unaided eye of man—to enrich the retinue of our sun, and to demonstrate the divinity of the human intellect.

This was the first great conquest of the calculus. But when it was turned upon things terrestrial, it exerted an influence less dazzling perhaps, but no less profound. It laid the foundations, more perhaps than any other one thing, for our age of brilliant invention and startling discovery. Great generalizations have sprung from active imagination and patient accumulation of facts. But these usually have a far richer content than their first announcers dream of. The calculus analyzes these great thoughts, recombines them and produces results the most unexpected and important.

Much of our polite learning has been in the possession of the world for two thousand years or more, but the peculiarity of our present civilization is the general diffusion of knowledge and the triumphs of engineering skill. Invention and machinery have multiplied man-power by twenty. And below it all lies the calculus. The successful engineer who would be anything but a mere slavish copyist must have a mind well founded in mathematics.

Let us refer briefly to some of the things which calculus has done or helped to do in engineering. We may say with little danger of contradiction that the engineering of to-day is a question of minimum causes and maximum effects—a question of the first differential coefficient.

A Tay bridge disaster reveals a crime against humanity. We wonder at the pyramids and temples of Egypt, but when we think of the lives sacrificed like flies in these colossal but useless works, where the means employed were vastly out of proportion to the ends sought, here, too, was a crime against humanity.

It is equally beneath the dignity of the disciplined man to put too much or too little into a structure to serve its designed purpose in use and beauty.

In hydraulics, calculus investigates water pressure on a submerged surface and center of pressure for same, thus determining the size and form of retaining walls of all kinds, and solving the first problem of a water supply. It also investigates the quantity of discharge through orifices, notches and overweirs, determines the most economical sections of conduits and canals, the time of emptying or filling locks or other vessels under a varying head; the maximum range of jets from a given inclination determines empirical formulae from experimental data by the aid of least squares; discusses non-uniform flow in rivers and back water curve above dams; discusses the maximum work derived from moving vanes, such as stationary water wheels, wheels of steam boats, and screws of propellers.

Fifty years ago an excellent engineer by the name of Uriah Boyden spent weeks in designing the buckets of a water wheel. He obtained correct forms, but by the aid of the calculus a man no more talented naturally may to-day do the same work in two or three hours.

In machinery and structures it investigates the work absorbed by friction of pivots and the like; moments of inertia and centers of gravity leading to transverse strength of beams, their deflections, slopes and elastic curves; it establishes the strength of thick hollow cylinders and spheres upon which is based the design of fire-arms and ordnance; computes suspension bridges; determines stresses in arched ribs of iron, steel, or timber, or in stone arches.

It gives the mathematical theory of maps, derives formulae for computing geographical co-ordinates and for map projection; adjusts observations in triangulation and determines the probable error.

It analyzes and improves the steam engine; it studies the effects of reciprocating parts, studies the balance wheel, the shaft, rods, and cranks: it enters the steam box and discusses steam pressure, horse power, and efficiency. It measures the contents of irregularly shaped vessels.

It may sometimes seem that the problems along these lines have been worked out and embodied in the shape of formulae and that there is no more use to study the method further for these purposes. That, however, is not true. A man should always be master of the tools he is using if he wishes the best results. The man who can derive a formula understands best its applications and limitations. Moreover, occasionally new and important questions arise which can not be answered at all unless one is versed in the use of the calculus.

It has largely developed the dynamo and has given us Fourier's series upon which the theory of this machine rests.

Klein once said to a former pupil of his:

"You know that I have been too busy with theoretical matters to keep up with the practical things; what is the greatest recent discovery in the application of electricity to the arts?" The pupil replied: "The greatest recent discovery in electrical engineering is a method by which a current may leave a long circuit at a higher potential than it entered it." This is the well-known principle by which Niagara Falls, for example, becomes available many miles away from the fall itself, as a source of power. Klein said: "Wait. That," he presently exclaimed, "depends on the second differential coefficient."

Problems such as I have thus far alluded to are the problems of civilization. Light, heat, power, architecture, water supply and distribution, dissemination of news, transportation—did you ever think how closely these things affect us? Chemistry and mathematics have done their best in providing for our locomotive a rail that would resist the strain of a

40-ton car and an 80-ton engine. The 40-ton car is the ship of the plains. Without it millions of acres now dotted by happy homes would have been unavailable for settlement.

Up to this time but a small per cent. even of our educated people have been imbued with the spirit of the calculus and have appreciated its power. Indications point to a large expansion in the near future in the number of those who will cultivate it for the power that it will give.

A popular German treatise upon this subject has recently been written expressly for chemists.

The object of this treatise is easily deduced from a remark in it quoted from Jahn in his elements of electro-chemistry. He says: "Chemists must gradually accustom themselves to the thought that theoretical chemistry without the mastery of the elements of the higher analysis will remain for them a sealed book. For the chemist the differential or integral sign must cease to be a senseless hieroglyphic if he will avoid the dánger of losing all comprehension of the theory of his subject, for it is fruitless labor to attempt to make clear in many weary pages what an equation says to the initiated in a single line."

By the higher analysis Guldberg and Waage have obtained formulae for studying the course and end of a chemical reaction. Neither in the application of analysis to chemistry are mathematical difficulties seriously in the way. The inner nature of the physical or chemical process is represented as truly by the method and working of the higher analysis as an object is represented by its photograph.

The power of the analysis in nature lies largely in its ability to deduce instantly from one set of laws another set equally important which at first sight do not seem to be closely related to it. For example, knowing the law of motion in space, we deduce velocity at any instant; knowing the chemical reaction as a whole, we deduce its intensity at any moment; from the weight of air and the law of gases we deduce its pressure at any height.

To the chemist we must look for the solution of many problems, whether of theory or practice. Perhaps the greatest of these is *the* philosophic question of the ages—*the nature of matter.* If this question is ever definitely settled it will be by the chemist, with the aid of the calculus.

The higher analysis in its services to mankind is not confined to the exact sciences.

Those who cultivate the natural sciences, so called, have been making and sifting vast accumulations of important facts with an enthusiasm, energy, patience and self-devotion which form an impressive illustration of the self-denial, the intelligent consecration of self to the race, the sublime purpose in life of the educated man of to-day. Where in history will you find finer examples of chivalric self-renunciation than are occurring among these men and women every day? Natural history has had its profound generalization. From the nature of the scientific laws of the origin of species, and from their fancied bearing upon religion as well as science, every foot of ground has been bitterly contested. Even to-day Darwinianism has many confident enemies. The controversy has reached that stage, however, where something akin to mathematical demonstration is needed if the theory would make further serious advance. To this last chapter Indiana is worthily making its contribution; but when an attempt is made to discuss observations and establish results upon higher ground, the calculus again comes into requisition. Indeed, so should it be, as the problem here presented is simply this: Can small accidental variation be integrated into specific differences?

Geology in its dynamical aspects, in its discussions of the earth's interior, and in questions of time necessary for the deposition of strata under varying conditions must sooner or later resort to the infinitesimal analysis.

To these will be added surface problems similar perhaps to the one suggested by a geologist. He asked that the calculus should be applied to determine the way in which varying temperatures apart from rain or frost may round off angular fragments of rock.

As political economy grows in certainty and increases in exactness, it is found that it becomes a proper field for the higher analysis. Economists, in fact, who desire to get the full content from the material which they try to interpret and generalize are coming to the calculus for an essential part of their equipment. In 1838 Augustin Carnot wrote upon the mathematical principles of the theory of wealth. Recently this has been translated in America, and a Yale professor has published a little work on the calculus to enable those to understand it who are untrained in higher mathematics. In all products which may freely invite competition there are certain ascertainable relations among quantity, demand, price and profit. These are expressible in analytic form, can be operated upon by the methods of the higher analysis and the result can be reduced to rational laws for the control of trade.

When the diversified interests of our country have been thus subjected for a period of years to statistical investigation and these results again have been formulated into equations of condition which in turn may be operated upon by the prolific methods of the mathematician; when finally the laws thus deduced have been published, read and understood, we may hope that commerce may be something besides a shrewd guess and that its shores will not be strewed with the wrecks of the hopes of 95 per cent. of those who embark upon its uncertain tides.

In 1815, Elkanah Watson, the well-known promoter of the Erie Canal, made his famous prophecy concerning the rapidity of the settlement of the United States. Some will remember how marvelously accurate this prophecy was fulfilled up to the sixth decade. But, beginning with the census for 1870, a wide divergence set in. At first the large deficiency in the observed population of 1870 was naturally attributed to the influence of the civil war. The mathematicians, however, soon began to analyze the returns and they discovered that the havoc and distress of our great conflict was quite inadequate to account for the change in rate of increase. As a result of these purely mathematical investigations, our sociologists began to search for the new conditions which were so profoundly affecting American life. They found them in the increase of luxury, in the more expensive habits of living then introduced, which tended to check the size of American families. So, analysis applied to sociological questions can not report on more forces than have been entrusted to it, but it may call attention to the fact that new and unknown causes have entered into problems under discussion and show where they first made their appearance. Thus it may lead the way to discoveries of vast moment in the sum total of human knowledge.

To what is our analysis leading us? Who can tell? It is certainly gradually arming us with powers comparable to those of the fabled Martians of recent Cosmopolitan fame.

Faraday was probably an abler man than Maxwell. The former developed many ideas which would not have occurred to the latter, but he was no mathematician. Maxwell took up the results furnished by his predecessor and worked out by the calculus the electro-magnetic theory of light, deducing many curious things which could never have occurred to Faraday.

Our warrior no longer wears mail and carries the cumbrous shield, spear, and battle ax, but we arm him with the Krag-Jorgensen and he strikes his blow from as far away as he can see his man.

Who will set the limits to our advance? As our knowledge becomes more exact, the application of our analysis will widen till it embraces man and nature in all their essence and relations.

Woollen's Garden of Birds and Botany. By W. W. Woollen.

Woollen's Garden of Birds and Botany is situated due northeast from the city of Indianapolis, on the south bank of Fall Creek, and is nine miles from the Indiana Soldiers' Monument, the center of the city, and four and a half miles from its corporate limit. It consists of forty-four acres of land, being four acres larger than Shaw's Garden, near the city of St. Louis. About twenty-nine acres of the garden is woodland, and the remaining fifteen acres are in cultivation.

It has a river front of one-third of a mile, and this is covered with timber and vines. The cultivated portion, most of which is rich bottom land, lies between the river front and the woodland. This is divided by strips of timber into three irregular parts and susceptible of being made very useful and attractive. In it, with little expense, two lagoons can easily be made for the growing of water plants. The river front can be admirably adapted to the same use.

The timber land consists of three hills, extending from the south to the north, the projections of which gracefully slope to the cultivated land, forming two perfect amphitheaters overlooking the cultivated land. These amphitheaters are exceedingly beautiful, the line of timber on them coming down to the very edge of the cultivated land and encircling it on the north with curved lines as true as could be drawn by a landscape gardener.

The hills are from one hundred to one hundred and twenty-five feet high, and divided by spring rivulets, which have rocky bottoms and beautiful meanderings. On one of these hills, in the very depths of the forest, is an immense bowlder, and on another a very considerable mound, which tradition says is the grave of an Indian chief. None of the hillsides are precipitous, and because of this, every inch of their surface is adapted to the growing of something, and in fact is covered with wild plants. On the projection of one of these hills are to be found more hepaticas and trilliums than at any other place in this section of the country, and on one of the hillsides about three-fourths of an acre is covered like a meadow with celandine poppies.

The native wild plants have never been disturbed in this piece of forest, it having never been pastured, and here I have found growing a greater variety of trees, shrubs, vines, herbaceous plants and fungi than in any other place that I have seen in all the tramping that I have done, and I have been a tramp all of my life. No amount of money or labor that could be expended by man could make such a garden as has here already been created by God. Truly, it has been written: "The heavens declare the glory of God, and the firmament showeth His handiwork." "His works are done in truth;" "the earth is full of the goodness of the Lord."

The primary idea I have in mind is to preserve these "wondrous works," just as they are, for all time to come. My second thought is that to this garden shall be brought, planted and preserved every tree, shrub, vine and plant not already growing in it, which now grows, or has heretofore grown, in Indiana; in other words, that the garden shall represent the botany of Indiana.

Of the birds it is written, "and not one of them is forgotten before God." Then, why not we have considerate care for them? Again, it is written: "Yea, the sparrow hath found an house, and the swallow a nest for herself, where she may lay her young." This embodies my thought as to what the garden is to be for the birds. That is, that it is to be their home, and a place where they can have their nests and raise their young without molestation. The garden is peculiarly favorable for both land and water fowls, and every effort will be made to make it a favorable stopping and breeding place for them. In doing this, special attention will be given to the planting of trees, shrubs and vines that produce fruits, berries and nuts, so that they, the squirrels and the like, may have plenty of food.

My hope is that provision may be made for a library and appliances for the study of natural history, in connection with the garden, and that the whole may be in charge of a curator.

I was born in the city of Indianapolis; what little college education I have was obtained at Butler College, and the Indiana Academy of Science has honored me with membership in it. And so I have it in mind to vest the title to the garden in the city of Indianapolis, and when I have done with it, to place it under the control of the Superintendent of the Schools of Indianapolis, the President of Butler College and the President of the Indiana Academy of Science for the joint benefit and use of the bodies represented by them. In doing this, I expect to have the hearty support of these bodies, and the labor and pleasure of developing the garden shared by them.

At my time of life and with my limited means, I can not hope to do more than to get the garden fairly under headway. I have, however, an abiding faith that ultimately it will become "a beautiful book of living nature."

Plans for the New Buildings of the Biological Station.

By Carl H. Eigenmann.

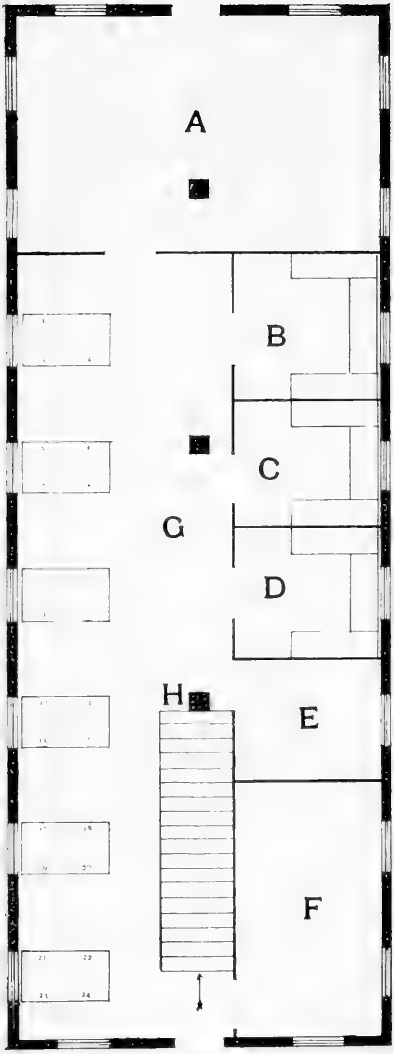
The Indiana University Biological Station, established on Turkey Lake in 1895, will be moved to Eagle Lake (Winona Lake), eighteen miles from its present location. Buildings will be erected by the Winona Assembly and Summer School Association after the plans 1, 2, 3 and 4.

Plan 1. Lower floor of the zoological building.

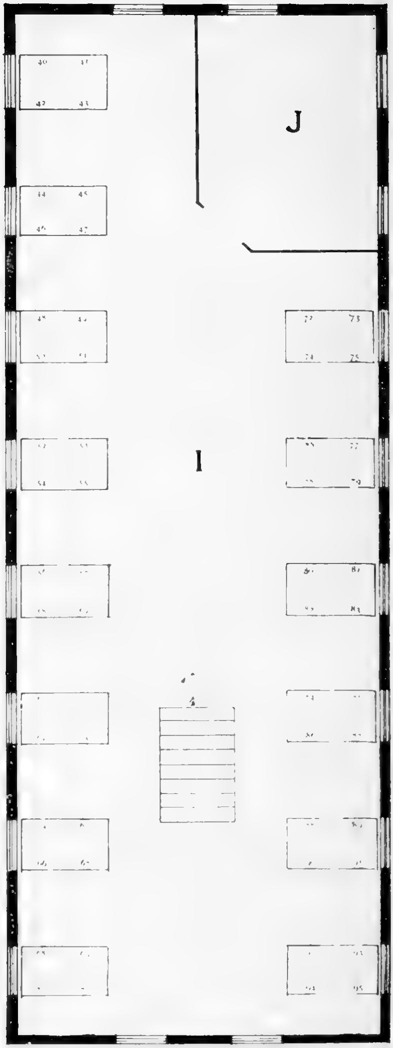
- (a) Director's office.
- (b) Private laboratory.
- (c) Private laboratory. Assistant in charge of the building.
- (d) Private laboratory. Dr. Dennis.
- (e) Photographic room.
- (f) Assistants' room.
- (g) Lake survey laboratory.
- (h) Dark room under the stairs.

Plan 2. Second floor of the zoological building.

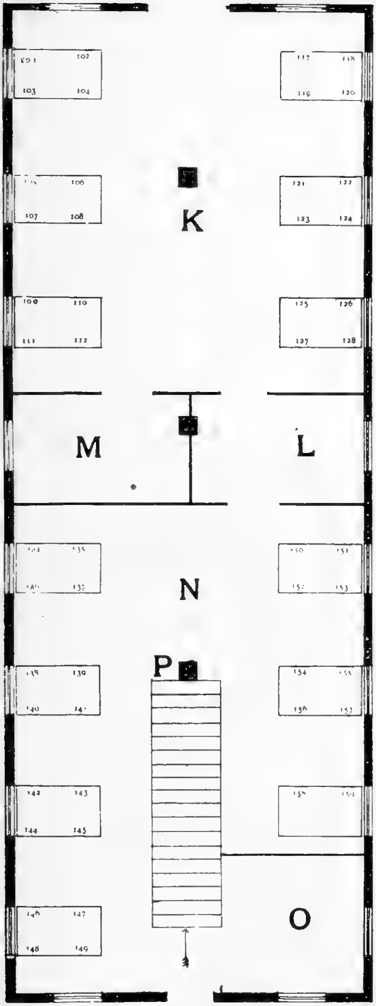
- (i) General zoological laboratory.
- (j) Dr. Slonaker's private laboratory.



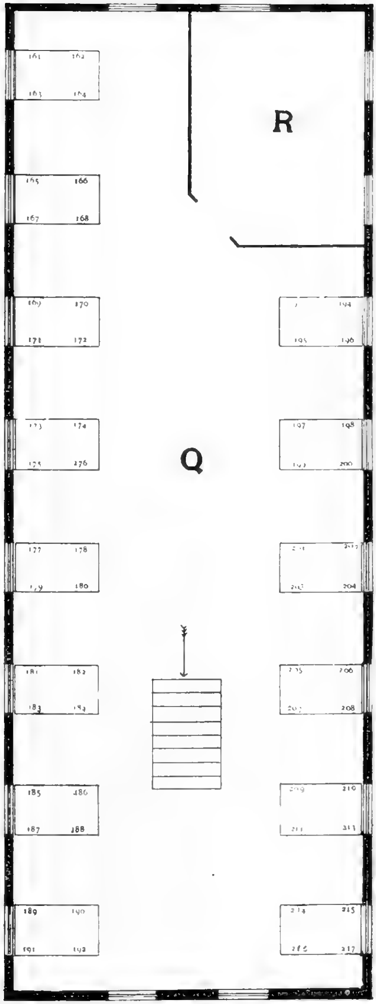
Plan 1.—Lower Floor of Zoological Building.



Plan 2.—Second Floor of Zoological Building.



PLAN 3.—LOWER FLOOR OF BOTANICAL BUILDING.



PLAN 4.—SECOND FLOOR OF BOTANICAL BUILDING.

Plan 3. Lower floor of the botanical building.

(k) Embryological laboratory.

(l) Microtomes.

(m) Assistants in charge of the building.

(n) Bacteriological laboratory.

(o) Dr. Lyons's private laboratory.

(p) Dark room.

Plan 4. Second floor of the botanical building.

(q) General laboratory.

(r) Dr. Mottier's private laboratory.

Slight modifications may be made in these plans during the construction of these buildings. They will be ready for occupation June 1, 1899.

Explorations in the Caves of Missouri and Kentucky.

By Carl H. Eigenmann.

Through a grant of $100 from the Elizabeth Thompson Science Fund and the liberality of the Monon, Louisville & Nashville, Louisville, Evansville & St. Louis, and St. Louis & San Francisco railroad companies, I have been able to put two short vacations to the best use possible. The first week in September was spent in southwestern Missouri and the southeastern part of Kansas.

While much incidental information was gathered concerning caves and cave animals, the chief work of the trip was to visit Marble Cave in Stone County, Rock House Cave in Barry County, Spring, Day's, Wilson's, and Carter's caves in Jasper County, and a cave whose name I have lost, east of Springfield in Green County, Missouri. The actual results were obtained in Marble Cave, Rock House Cave and Day's Cave.

To reach Marble Cave it was necessary to travel nearly forty miles from the railroad over a rough country well deserving the name of Stone County, for in some places it was a speculation where the inhabitants were able to secure mud enough to stop the chinks in their log houses. Marble Cave opens at the top of a hill that is, I was told, 675 feet above White River, a short distance away. The entrance leads down over a winding stairway and around a pile of fallen debris for over a hundred feet. The object in quest of which I came to this place was the very rare cave salamander, Typhlotriton. It was found in a low passage, so low that going on hands and knees was in many places out of the question. The process of going snake fashion was facilitated by the slippery roof, and, in many places, a muddy floor. A layer of water of varying depth covered the floor. In this water, under rocks, I found the salamanders. It is worth pondering that here, many feet under ground, this salamander has retained the retiring habits of its confreres of the upper surface. I secured four adults and two larvae at this point. One of the adults I met coming down a slippery slope on all fours, while I was going up in the same fashion.

Rock House Cave is reached from Exeter on the Frisco line by a little railroad that runs down hill all the way to Cassville, and thence by buggy to Rock House Cave. Evidently there formerly was an extensive series of underground streams here. The main cave has been obliterated by erosion, which has cut down below the former level of the main cave. As a result we find here a deep, narrow valley with small tributaries emptying into it from caves opening high up on the sides of the valley in little gorges. The largest of these is Rock House Cave, with an entrance large enough to serve as a carriage house. In the gravel of the bed of the small rivulet coming from this cave I secured an additional lot of larval Typhlotriton, but could find no more adults. This cave I entered twice by myself.

Day's Cave I had visited a year before when I sat, lamenting and in impotent rage, at the mouth of this hole in the ground. It was full of water, the mouth choked up and I could not get in. Now I came with plans for excavations which I would set on foot while I went elsewhere to look for game. To my delight I found that some enterprising citizens had dug a neat passageway into this cave to see what could be done with the water to supply the town of Sarcoxie. It was still necessary to crawl to get in, but I was at once rewarded, for I caught the new genus of blind fish described in the proceedings of this Academy last year as Typhlichthys rosae. I entered this cave twice in one day and secured eight fishes.

I was induced to go on a fool's errand into Kansas by the things described by an old miner with a string of scintillating expletives as being common in the drifts of the extensive mines of that region. But aside from a little experience nothing was gained on this trip.

On November 22d, I started for Mammoth Cave. The objects I especially wanted were the very rare Chologaster agassizii, specimens of Amblyopsis from south of the Ohio, Typhlichthys subterraneus and the cave rat, Neotoma. Mr. H. C. Ganter, manager of Mammoth Cave, did everything in his power to make my trip both successful and pleasant.

Although all the likely places were examined, not a single Typhlichthys or Amblyopsis could be found. After a day in searching for Chologaster, when almost despairing, we found, in a little pool of the river Styx, several of these very rare fishes lying on the bottom. As soon as my net touched the water they were off, and since the mud at the bottom was very easily riled but two specimens were secured. Next day the same spot was visited, when two more specimens were secured.

A horse-back ride of several miles brought us to Cedar Sinks. The roof of an enormous cavern has here fallen in ages ago. At one end the overarching rocks, which form part of the sides of this ancient dome, still bear witness to the existence of a former stupendous structure which covered several acres of ground. At the bottom of this cliff a few small openings lead into caves. One of these, judging from the strong current of air passing into it, must be a large cave. In these caves an additional specimen of Chologaster, the largest secured, was taken, and this repaid amply for all the trouble it had cost to come.

One cave rat was killed in Audubon Avenue in Mammoth Cave. An account of this rat, as well as of Chologaster, will appear elsewhere.

One other catch of great importance was made. I secured a specimen of Cambarus pellucidus with young. A good series of these has been preserved for future study.

A few words should be added about Mammoth Cave itself. I came to this cave the second time, regarding it simply as a locality harboring cave animals. Opportunities came to see much of the cave, and I must confess having become impressed with the value of the scientific problem the cave itself presents and the absorbing interest of its scenery. There are really four tiers of caves, one above the other. The upper two stories are dry, but the lowest contains water permanently. The present outlet of the cave is practically on a level with Green River at its low stage, and if the size of the cave increases it can only be by dissolving the bed rocks of the Echo and Styx Rivers. The water is said to rise sixty feet and more during heavy rains, the outlet of the cave streams being very small. The different levels of the cave are joined by direct channels, by long and devious channels and by wells, some of which, like the Mammoth Dome, are 150 feet from top to bottom. The floor of the main cave is on the second level, while its roof is on a level with the roof of the fourth tier. We can easily imagine that when the Green River had cut through the sandstone overlying the limestone in which the cave has been formed, an outlet for water collecting in the crevices of the limestone was found near the present entrance of the cave. The main crevice developed into a large stream, cutting down and dissolving the rock much more quickly than its smaller tributaries. The tributaries fell into the main stream in little cascades and their floors, the present fourth level, remained permanently above the main cave or second level. As Green River cut through its limestone bed a lower exit was opened for the waters of this primeval mammoth river, and later still, a lower. By the formation of the pits and winding channels the water finally permanently abandoned the upper channels and is found now only in the lowermost levels. When this process began only aquatic animals could enter the cave. Even after the cave had become quite large it probably became full to the top during floods. This is still the case in many caves of Indiana. As a matter of course only aquatic animals were able permanently to establish themselves. But when the upper levels became permanently dry other animals could and did enter the caves and others are evidently still colonizing them.

The scenic parts which make the most lasting impression are Echo River, the Mammoth Dome and the main cave. The main cave is simply a very large winding tunnel, not startling in any way, but by the time one has walked for an hour or two it begins to impress one very forcibly. The Star Chamber and Martha Washington Statue, in this part of the cave, are remarkable in their way. The echo of Echo River lasts but twelve or fifteen seconds. It is remarkable for the blending of simple sounds, not for the repetition of words or phrases.

Notes on Indigestible Structures in Articles of a Vegetable Diet.

By John S. Wright.

Many articles of a vegetable diet, especially those which are consumed in a crude or raw state, contain tissue elements which pass through the alimentary canal without losing their identity. Examinations of fecal matter show that all of the tissue elements from parenchyma to sclerenchyma may under various conditions pass through the entire digestive tract almost unaltered so far as general character is concerned. In some diseases of children and in disorders of the digestive organs it is necessary to make fecal examinations to complete the diagnosis. In several such cases which have come to my knowledge the presence of these vegetable cells has given rise to considerable speculation, particularly where the physicians were not familiar with plant histology.

In one case the presence of what afterwards proved to be parts of orange pulp was very perplexing; in another the attending physician was concerned over the repeated occurrence in the stools of shredded or fibrous matter. As the patient, a man, was being treated for dyspepsia, he was of the opinion that these fibres resulted from the epithelial layer of the intestines. On submitting them for examination, they proved to consist wholly of tracheary tissue, mostly pitted vessels. In his examination, the physician had taken each pit to represent an animal cell. On inquiry it was learned that the patient, during the time his feces contained this material had eaten freely of small, fibrous sweet potatoes, which were likely the source of these pitted vessels. The above and other cases have suggested to me that further histological studies of the common articles of our vegetable diet would prove of practical value from both the medical and botanical standpoint.

The Action of Mercury and Amalgams on Aluminum.

By Geo. W. Benton.

Some Field Experiments with Formalin. By Mason B. Thomas.

At the last December meeting of the Academy we made a preliminary report on the effects of formalin on germinating seeds. As stated at that time, the experiments were conducted in the greenhouse, where all of the conditions could be properly controlled and the best results secured. This work was intended to be preparatory to the field experiments to be tried early in the following spring.

The field experiments made with corn and oats were so striking that their results warrant publication and general application in the dealing with the smut of these two cereals. The laboratory experiments showed that the seeds of various plants would allow of only a special treatment with a certain definite strength of solution. The results of these tests gave us a basis for our field experiments and made this part of the work much easier.

The experiments of last year showed that wheat can safely be treated with a one-fourth per cent. solution of formalin for one-half hour, oats with a one-half per cent. solution for three hours and corn with a one-half per cent. solution for one hour, without interfering with their germinating powers.

The field experiments were tried with oats and corn on the farm of Mr. Henry Davidson near Whitesville, Ind. The oats to be treated were soaked for one-half hour in a one-half per cent. solution of formalin and then, without drying, sowed broadcast and the field dragged. Untreated seeds were sowed in a plat of ground alongside of these, and careful records made of the developments. The seeds in the two plats germinated at the same time and showed, so far as early appearances were concerned, no differences as a result of the treatment. The mature plants of the treated seeds were slightly smaller than those of the untreated ones, but the amount of grain produced was the same in both cases, except for the difference occasioned by the presence of the smut.

Upon ripening, the plants of the untreated seeds showed six per cent. of smutty heads, while none of the plants of the treated seeds had even a trace of smut about them, thus vindicating the value of formalin as a fungicidal agent.

In the experiments tried with corn, the seeds were soaked in a one per cent. solution for one hour and then dried in the sun. This treatment was more severe than that found advisable in the laboratory experiments. As a result the seeds were somewhat delayed in their germination and in some cases the plumule was not visible above the ground until two or three days after all of the untreated ones, planted in a corresponding plat alongside of these, had made their appearance. This inequality between the plants of the two plats was not of long duration and at maturity no difference in size and development could be detected between the plants of the two plats. Of the plants from the untreated seeds two per cent. were attacked by the smut while none of those of the untreated seeds showed any signs of the fungus. These results with corn show the possibilities in this direction. Of course infection during the growth of the plant would not be prevented by this treatment. The treatment is not difficult, and the actual expense for the cost of material is not over six cents per acre.

Comments on the value of formalin as a fungicide are not necessary in view of the facts as presented.

Extensive arrangements are being made for experiments the coming spring on ground that has in years past produced crops showing a loss of from forty to sixty per cent. from smut.

The Resistance of Cereal Smuts to Formalin and Hot Water.

By William Stuart.

In connection with some studies on the comparative merits of formalin and hot water in the prevention of smut in wheat and oats, the subject of the resistance of the smut spores when treated separately was considered of sufficient importance to warrant investigation. The smuts of wheat and oats were selected from the fact that these two cereals are the only ones of economic importance in the State which it is possible to treat successfully for smut. While it is possible to kill the spores of corn smut by treating the seed, it affords no guaranty that the plants will be free from smut. This is owing to the fact that the method of infection by corn smut is unlike that of the other two cereals, inasmuch as the corn plant is liable to infection at any point where there is young, growing tissue, and at any stage of its development.

In order to test the relative resistance of smut spores as compared with the grain itself, separate lots of each were treated side by side in the same solution.

The smut spores used were those of the loose smut of wheat and oats. These were obtained from a quantity of smutted heads collected last summer from badly infected fields. When required for use the smutted portions were removed and passed through a sieve to get rid of the coarse particles. The spores after being well mixed were collected in a box and formed a supply from which successive portions were taken as required for treatment.

In treating the smut spores and grain, considerable care was exercised in furnishing conditions which would insure similar treatment for all. This was especially necessary, as in the case of the hot water treatment it was found that in the high temperature treatments a difference of about five degrees occurred between the upper and lower surfaces of the water in a three-gallon bucket. To obviate any possibility of one lot receiving different treatment from that of another, especially when both were treated at the same time, the following method was adopted: The smut spores were enclosed in fine muslin sacks, weighted by tying a few grains of shot in the corner of them. The grain, about half an ounce being used, was put in loose muslin sacks, similarly weighted. The sacks were suspended on a rod, at a uniform level. When ready for treatment they were dropped into the solution, the weights instantly carrying the sacks below the surface, while the rod rested across the top of the vessel, thus holding them in place. The water at the level of the sacks was maintained at the desired temperature. In each instance the five and ten minute treatments were made at the same time, the removal of the former being readily done without in any way disturbing the remaining ones.

The treated spores were germinated in hanging drop cultures in moist Van Tieghem cells. Control cultures of untreated spores were mounted in the same manner. The spores were germinated in distilled water. Whenever any doubt existed in regard to the behavior of the cultures, fresh mounts were made. Cultures of the treated spores were made as soon as possible after their removal from the solution.

The grain was germinated in the laboratory in a Geneva germinator. As only a small quantity of seed was treated, but two hundred seeds were used in the germination experiments. The germinating seeds were counted and removed from the germinator each day until germination ceased.

The results of the work performed are given in Tables I. and II. It will be noticed that these do not include anything upon wheat smut. In explanation of this, the writer wishes to state that, at the beginning of the experiment, the germination of the wheat smut spores was very unsatisfactory; frequently none would germinate in the control cultures. As the work progressed the viability of the spores decreased until practically none grew. Under these circumstances it was thought best not to present any of the data.

TABLE I.

Germination of Oat Seed and Smut Spores After Immersion in Formalin Solution.

Per Cent. of Formalin.	Length of Immersions.	Number of Spore Cultures.	Number of Cultures Showing Germination.	Per Cent. of Grain Germinated.
Control	....	12	12	99.5
One-fourth	15 min....	4	0	92
One-fourth	30 min....	4	0	93.5
One-fourth	1 hour....	4	0	90.5
One-fourth	2 hours...	2	0	95
One-half	15 min....	4	0	92.5
One-half	30 min....	2	0	91
One-half	1 hour....	2	0	91
One-half	2 hours...	2	0	86.5

As will be seen by Table I. but two strengths of formalin were used, these being a one-fourth and a one-half per cent. solution. These two strengths were chosen because they were considered sufficiently strong to prove effective against smut when it was immersed but a short time, and would therefore more nearly represent comparable conditions with hot water treatments. In these two solutions the grain and smut were immersed for periods of time varying from one-quarter to two hours, the intervening points being one-half and one hour, making in all four treatments.

Taking the shorter treatment by the weaker solution, it was found that even when a minute quantity of spores was treated, if they were mounted at once in a hanging drop culture, quite a large per cent. of the spores would germinate. If, on the other hand, the spores were allowed to remain in the sacks until dry and then mounted, no germination was obtained. The same results were also obtained in the half-hour treatment, and not infrequently an occasional spore in the hour treatment.

Spores treated one-quarter hour in the one-half per cent. solution would show slight germination if cultures were made as soon as removed from the solution, but if allowed to become dry and then mounted no spores germinated. The longer periods of treatment gave no germination whether cultures were made at once or after the spores were allowed to become dry.

In the treatment of smut spores with formalin it was found that if what ordinarily might be called a small quantity of spores were taken very variable results were obtained. This seemed to be due to the imperviousness of the spores, when any number were collected together, to the formalin. This feature did not appear to enter into the hot water treatment, apparently they were not impervious to the hot water. Probably this was largely due to the somewhat oily properties of the formalin.

Another notable feature of the formalin was its action on the spores after their removal from the solution, and which in the shorter periods of treatment resulted in no germination of the spores, as against fair germination in those mounted as soon as removed from the solution.

The formalin used was that known to the trade as "Formaldehyde. Merck," a supposedly genuine forty per cent. formaldehyde solution.

Some indirect references have been found in regard to the action of formalin on smut spores. In one of these references the author[1] found that the spores of species of *Ustilago* and *Tilletia* were killed after treatment for two hours in a one-tenth per cent. solution of formalin. In a discussion following the presentation of the paper, Krüger stated that spores of *Ustilago carbo* were not killed by immersion for twenty-four hours in a .05 per cent. formalin solution.

E. A. de Schweinitz[2] says that a formalin solution of 1:10,000 has been recommended for destroying the spores of smut.

The effect of formalin upon germination of the seed was not very well marked. A slight injury was noticeable, but the percentage of germination was good.

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[1] Geuther; Ber. Pharm. Gesell., **5:** 325–330, 1895; Abs. in Chem. Centr. Bl., 1896; Abs. in Jahresb. Agr. Chem., **19:** 418; Abs. in Bull. Ind. Agr. Sta., **65:** 34; Abs. in Exp. Sta. Record, **9:** 569.

[2] Yearbook Dept. Agr., 259, 1896.

TABLE II.

Germination of Oat Seed and Smut Spores After Immersion in Hot Water.

Temperature of Water.	Length of Immersions.	Number of Spore Cultures.	Number of Cultures Showing Germination.	Per Cent. of Grain Germination.
Control	... .	14	14	99.5
110° F.	5 min....	2	2	....
110° F.	10 min....	2	2	....
115° F.	5 min....	2	2	....
115° F.	10 min....	2	2	....
120° F.	5 min....	4	3[1]	....
120° F.	10 min....	4	0	....
125° F.	5 min....	1	0	93.5
125° F.	10 min....	2	0	94 5
130° F.	5 min....	1	0	90.5
130° F.	10 min....	1	0	88
135° F.	5 min....	1	0	95
135° F.	10 min....	1	0	93
140° F.	5 min...	1	0	53
140° F.	10 min....	1	0	42.5

In Table II. is presented the result of the hot water treatment, the range of temperature being from 110°—140° F. The lowest point of effectiveness was found to be 120° F. for ten minutes. This is a point at least ten degrees below the effective point of treatment of the grain for the prevention of smut[3]. The grain itself showed little injury from treatment at an increased temperature of fifteen degrees over the effective point for smut. The inference to be deduced from this fact is that in the hot water treatment there is quite a marked range in temperature between the limit of spore resistance and that of the resistance of the grain. The effectiveness of the treatment between these two limits would seem to depend wholly upon the ability of the operator to bring each seed in contact

[3] Arthur, Ind. Agr. Exp. Bull., **35:** 86, 1891.

with the hot water a sufficient length of time to reach all the smut spores.

Of formalin it may be said that, although it is a comparatively new fungicidal and germicidal agent, it has nevertheless been employed to quite an extent in the prevention of parasitic diseases. So far as known it was first employed in this State by the botanical department of the Agricultural Experiment Station at Purdue during the winter of 1895-'96 in the treatment of scabby potato tubers for the prevention of the scab[4]. The treated tubers were grown in the greenhouse, and the resultant crop gave such satisfactory results that more extensive trials were made in the open field during the season of 1896. The results of these trials have been reported in the bulletin already cited.

Two experiment station bulletins are known to have been issued containing reports of trials with formalin for the prevention of wheat and oat smut. The first of these[5] reports the use of formalin in the treatment of wheat and oats. The author found a solution of one pound to fifty gallons to be effective when the seed was given a two-hour treatment. The other bulletin[6] referred to contains an account of the use of formalin for the prevention of smut in oats. It was found that smut spores were destroyed by immersing the seed two hours in a 0.2 per cent. solution.

In an experiment performed last summer by the Botanical Department of Purdue University and not yet reported, it was found that oats immersed ten minutes in a solution containing one pound of formalin to fifty gallons of water, only eight-tenth per cent. of smutted plants were produced as against over twelve per cent. in the untreated ones.

A recent newspaper article[7] contains a brief notice of some experiments with formalin by Prof. Thomas of Wabash College, in which he found that oats treated half an hour in a one-half per cent. solution produced plants entirely free from smut as against about six per cent. in the untreated ones.

A few references have been found on the influence of formalin on the germination of the seed. Geuther[8] found that soaking the seed grain two hours in a 0.1 per cent. solution did not injure its germination. In a

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[4] Arthur, Ind. Agr. Exp. Sta. Bull., **65**: 23, 1897.

[5] Bolley, North Dakota Exp. Sta. Bull., **27**: 1897.

[6] Close, N. Y. Agr. Sta. Bull., **131**: 1897.

[7] Indianapolis News, Dec. 9, 1898.

[8] *l. c.*, 325-330.

one-fourth per cent. solution for the same length of time the seed was seriously affected.

Bolley[9] reports the effects of formalin on oats, barley and wheat. Seed of oats and barley immersed half an hour in a solution containing three parts formalin to one thousand parts of water gave normal germination nine days and nine months after treatment. Wheat immersed ten minutes in a two per cent. solution gave eighty-two per cent. germination.

Thomas[10] finds a one-half per cent. solution for oats and a treatment of about two hours produces no injury to the seed.

For wheat a one-fourth to one-half per cent. solution and an immersion of one-half hour is recommended. Rye was injured in a one-fourth per cent. solution when immersed but an hour.

SUMMARY.

A brief resumé of the data presented shows that the results obtained in the treatment of the spores are well within the bounds of successful practice.

The spores are much more easily injured either with hot water or formalin than is the grain.

It is apparent that the essential feature in the successful treatment of grain for smut is to bring each seed in contact with the solution used a sufficient length of time to enable it to reach the smut spores.

The advantage possessed by formalin over hot water in the treatment of seed grain lies in the greater ease of its application, doing away with the necessity of heating water and maintaining a reasonably uniform temperature during the period of treatment.

Lake Maxinkuckee. By J. T. Scovell.

During the summer of 1898 I traced out the sandbars in the southern portion of the lake. In doing this work I made about 100 soundings. In all we now have about 900 recorded soundings of the lake. The contour

[9] *l. c.*, 130–132.

[10] Thomas, Proc. Ind. Acad. Sc., 148, 1897.

lines drawn from these soundings give a fairly correct idea of the topography of the lake bed.

Almost every sounding in five feet of water showed a bottom of hard sand or gravel, while almost every sounding in water ten feet deep indicated a bottom of fine mud, usually marl, from eight to twenty feet or more deep. In water more than thirty feet deep the mud is finer and darker, but I could get no idea of its depth. The hard bottom is much wider on the east side of the lake. It may be that the westerly winds give rise to an undercurrent which sweeps the finer material into the deeper water. But the same phenomenon occurs on the bars in the central portions of the lake where the wind would hardly cause currents. A few observations of the temperature of the water in the lake at different times of the day showed considerable variation and might cause currents. July 28th, at 7 a. m., the temperature in water about eighteen inches deep was 78 degrees Fahr., at 2 p. m. it was 84 degrees and at 8 p. m. 82 degrees; July 29th, at 7 a. m., 77 degrees, at 2 p. m., 87 degrees, at 8 p. m., 80 degrees; July 30th, at 7 a. m., it was 74 degrees, at 2 p. m., 82 degrees, at 8 p. m., 78 degrees; July 31st, at 7 a. m., 75 degrees, at 2 p. m., 84 degrees, at 8 p. m., 80 degrees; August 1st, at 7 a. m., 76 degrees, at 2 p. m., 82 degrees, at 8 p. m., 79 degrees; August 5th, at 7 a. m., 79 degrees, at 2 p. m., 82 degrees, at 8 p. m., 80 degrees; August 6th, at 7 a. m., 75 degrees, at 2 p. m., 80 degrees, at 8 p. m., 78 degrees. Whether changes of temperature ranging from five to ten degrees within twenty-four hours would cause currents strong enough to move fine sediment I cannot tell, but the idea is suggestive, and investigation along this line may show interesting results.

The lake shows considerable variations in level. Elevations taken by the Vandalia people at different dates in 1895, 1896, 1897 and 1898 show a variation from 733.3 to 735.17 feet, about 1.87 feet. In August, 1896, I saw a rise of six inches as the result of two days' rain.

I added over 100 species to my list of plants and trees found about the lake, extending it to about 290 species. We have a list of thirty-one species of fish found in the lake. Six species of bivalve mollusks and three or four species of univalves have been identified, and I think five species of turtles are found about the lake.

An Elevated Beach and Recent Coastal Plain Near Portland, Me. Notes of an Excursion with a Party Under Conduct of Prof. Wm. M. Davis, July, 1898. By Wm. A. McBeth.

[Abstract.]

Evidence pointing to the existence of such beach and recent plain in southern Maine as observed in the region of Portland are a belt of sand and gravel deposits closely following the three-hundred-foot contour line around an arm of the Casco Bay depression. The belt is quite continuous through the distance traced and apparently much further, and it slopes gently down toward the inclosed valley. Exposures along streams and in gravelpits, wells, etc., show depth and character of deposits. What are apparently sandpits modify the course of some of the streams crossing the deposits. Several drumlins stand on the upper border of the belt with bluff frontages upon it, which resemble the wave-cut drumlins in Boston Harbor. Undercut cliffs of rock also front upon it with heavy water-worn talus fragments at their base. The country falls off abruptly in places from the lower edge of the belt to the basin below. The floor of this depression is covered with a light gray marine clay, the drainage channels of which are narrow and steep-sided, showing recent origin.

The deposits of sand and gravel are thought to be a beach line elevated about 300 feet above the sea. Postglacial age is indicated by the wave-cut drumlins and undisturbed conditions of deposits. The much later age of the lower plain is indicated by the immature drainage lines and slight weathering. The order of movements evidently has been sinking of the region, deposition of clays in basin and formation of beach, elevation of from three hundred to four hundred feet, redrowning of the lower levels of the basin.

Wasted Energy. By Prof. J. L. Campbell.

A Vesuvian Cycle. By C. A. Waldo.

Ordinarily Vesuvius is in a state of mild activity. A single visit, however, does not show the periodical aspects of its manifestations. It was the fortune of the author of this note to visit Naples in the summers of 1890, 1891, 1894 and 1896, and on each of these occasions to make the ascent of the volcano. The cinder cone has a diameter at its base of about one and one-half miles. It rests on a gently sloping hill, while its own angle of elevation is about 30°. This cone or new mountain is about 1,200 feet high and terminates in a comparatively level top, varying in diameter from 500 to 1,000 feet, and now about 4,200 feet above sea level.

In 1890 as we approached the summit we felt that it was shaken at intervals of about thirty seconds. Soon we noticed that the tremors were accompanied by a peculiar sighing and explosive sound. At the summit a cone of freshly-ejected material had been formed, forty or fifty feet high and 150 to 200 feet in diameter at the base. At each explosion a fountain of semi-fluid lava was projected to the height of 100 feet above the top of the crater. Most of this material rained back into the crater's mouth, into which we could not look, but much of it fell in fragments on the outside.

In 1891 the top of the cinder cone had undergone a complete change. The small cone surrounding the crater had entirely disappeared. In its place was a cavity 200 feet across and of unknown depth. The mouth of this cavity was filled with vapors and dark sulphurous gases which completely hid the boiling lava far below, and which, streaming into the air, gave to the mountain the appearance of smoking. But standing on the edge of the chasm a continual din deafened us and an occasional heavier explosion smote our ears.

In the Atrio del Cavallo, a deep valley to the north, between Monte Somma and the cinder cone, we could see the glow of fresh lava as it flowed from the mountain's side. During the previous year the hydrostatic pressure of the molten, liquid mass rising so high in the crater had forced an exit through the base of the cinder cone.

In 1894 lava no longer issued from the recent vent towards Monte Somma. During the intervening period, after the great pressure of 1890 had been removed, it had flowed more and more slowly until it began to clog the opening and finally sealed it completely. This vent, which in 1890 was in the direction of least resistance, must now be one of the strongest parts of the mountain. Thus one by one the weaknesses of the cinder cone are patched up until the conditions of strength are prepared which will compel the lava to flow out of the very top. Soon thereafter will follow a great eruption. Just as in 1891, there was in 1894, an open central crater, but by its continual "working" the mountain had filled up the bottom of the cavity, and the surface of the molten lava had risen to a point about 150 feet below the edge of the crater. We now saw repeated the conditions of 1890 with this exception, that the building-up process had not reached the summit. From a secure position we could look down upon the molten lava and observe all the phenomena of the immature eruptions.

In 1896 the rising column of lava had once more forced a way for itself through the mountain's base. Again the crater was a dark, roaring cavern. But this time the vent was in the direction of the observatory to the west of the summit. The liquid lava had covered many acres, destroying a part of Cook's carriage road, and piling up a new hill a hundred feet high. A few inches beneath the surface this hill was still red hot, while from its summit two or three streams of live lava flowed sluggishly down its side.

In about five years Vesuvius had passed through one constructive cycle. These must succeed each other until the walls of the crater have sufficient resistance to allow the accumulation of an explosive energy. Then comes the short destructive period during which the retaining walls are seamed and shattered. In general the number of elementary cycles between great paroxysms will be in direct proportion to the work of restoration necessary, and this in turn will depend directly on the violence of the eruption immediately preceding.

X-Ray Transparency. By Arthur L. Foley.

[Abstract.]

Many experiments have been made to determine, and many tables given to show, the relative transparency of bodies to the X Rays. No two have been in agreement. The varied results cannot be attributed to uncertain methods or experimental errors, or, indeed, to the size, shape and general construction of the different tubes used. The degree of the vacuum seems to be the chief factor.

Two of the tubes used in this investigation were of the usual type—non-adjustable vacuum. At first they increased in efficiency, then decreased, and finally almost entirely lost their power of affecting a fluoroscope or photographic plate. At first the rays possessed little penetrating

power; that is, bodies were rather opaque. But as the vacuum became higher the penetrating power of the rays became greater, especially for dense bodies.

The third tube used was one of Queen's adjustable vacuum tubes. To obtain what is here called a low vacuum, the auxiliary spark gap was closed or short-circuited. To obtain a high vacuum the gap was made as long as possible. A photograph of the hand with a low vacuum showed flesh and bones almost equally opaque, while with a high vacuum the flesh was almost transparent. A photograph of a piece of glass, aluminum, steel, carbon, rubber and cork showed that the glass, aluminum and steel were more transparent to the high than to the low vacuum rays. The reverse was true of carbon and cork. No difference was noted with the rubber.

Soon after the X rays were discovered Edison announced that what are known as slow plates are the fastest for X rays. Here again the degree of the vacuum must be taken into consideration. For high-vacuum rays fast plates are most rapid.

The fluoroscopic action of the rays also changes with the vacuum, a rather low vacuum giving the best results.

Whatever be the nature of the X rays it is certain that they possess properties analagous in some respects to pitch and color.

The Trouble with Indiana Roads By Daniel B. Luten.

A good road is defined as a road that is hard, smooth and serviceable at all seasons of the year.

The State of Indiana has 60,000 miles of wagon roads, of which about 8,000 miles have been improved by graveling or "piking," and now constitute our free gravel road system, maintained and repaired by the counties. The remaining 52,000 miles are nearly all dirt roads, and are maintained and repaired by the townships.

If we are to judge of Indiana roads by the above definition of good roads, we must admit that less than one per cent. of our 60,000 miles of roads are good roads. I do not mean that the remaining ninety-nine per cent. are always bad; but I do mean that for five or six months of every year they are bad, some of them extremely bad, and that at such times they are passable for none but lightly-loaded and slow-moving vehicles. From the middle of May until the middle of July the roads are in excellent condition. A dirt road during these months is a splendid road; a gravel road is equally good. From the middle of July until the middle of October they are covered with dust, sometimes two or three inches in depth. Then come the fall rains, and the dusty roads absorb water like a sponge preparatory to December frosts. Then follow three months of good roads with frozen surface over the imprisoned water that is well content to wait, knowing that in March it will have ample opportunity to make trouble. And with the first of March the roads begin to thaw and break up, to be followed by two months of bad roads.

Of the 60,000 miles of roads in Indiana, 52,000 are unrideable for bicycles at nearly all seasons of the year, and the remaining 8,000 are rideable only during about four or five months in the early summer and late in the fall or winter.

There are seven good reasons why our roads are bad:

1. Because of lack of drainage, more especially of the surface water; failure to remove the surface water to the side ditches promptly permits it to saturate and soften even the hardest of road materials. The road surface should at all times be kept shaped like a roof to shed water, and to this end it is necessary always to keep ruts and chuckholes filled, and the surface smoothly and uniformly crowned. The first step in the maintaining of a road in good condition is to eradicate the ruts. And any plan or device that will prevent the forming of ruts will aid in providing good roads. Wide tires help to attain this end; a more clever device is the long doubletree, with the whiffletrees so attached that each horse must travel directly in the wheel track. The horses refuse to travel in the rut, and choosing the smoothest path, the wheels are drawn out of the rut, thus helping to roll it down instead of cutting it deeper.

2. Another reason why our roads are bad is because repairs are too long delayed. On road surfaces, more perhaps than upon any other kind of engineering structures, the repairs should be made promptly; an ounce of prevention is worth many pounds of cure.

3. A third reason for bad roads is because too much of the work on repairs is done at one time, on the principle, doubtless, that if a small dose is good, a large dose will be better.

Our gravel roads suffer most from this method of repairs. Late in the fall they are heaped ten or twelve inches deep with gravel and then allowed to take care of themselves for another year, when they are given another dose, after which they are called "improved" roads!

The gravel is dropped in a heap in the middle of the road, usually with no attempt to spread it uniformly. And that is the fourth reason for our bad roads.

4. Too much material and too little labor. One-fifth as much new material would usually be sufficient, and the labor wasted in hauling the other four-fifths should be used in filling ruts and chuckholes instead.

5. Another reason is that the repairs are made at the wrong season of the year. Gravel roads are frequently repaired in the fall; then the heavy rains turn the new gravel into mush that freezes into a good road for the winter months, but breaks up into soft mud with the first thaw of spring.

The proper season for road repairs is all the time. They should be watched and repaired every day of the year.

6. Reason No. 6 is the use of improper road material. Broken stone applied to road surfaces should never be in sizes greater than one and one-half inches in diameter, and should contain at least twenty-five per cent. of stone screenings less than one-fourth inch in diameter. Gravel should be such that all of it will pass a one-inch sieve and twenty-five per cent. will pass a one-fourth inch sieve. Good road gravel contains no rocks larger than hulled walnuts; nor should there be more than five per cent. of clay present.

7. Another reason for bad roads is poor location; the policy of running roads on section lines is unwise, especially in hilly country. They ought to wind through the valleys and around the hills instead of over them. A proper location for a road is always a compromise between grades and distance. In hilly country the winding road will be an easier road for traffic, will be more picturesque and will frequently be shorter than the section-line road.

Having pointed out the reasons for bad roads, the next question is to find the remedy. I shall not propose better methods of construction; even macadam roads costing say three thousand dollars per mile would give us better service for but one or two years and then would become as bad as the rest if not properly maintained. There is only one kind of road that can be depended upon to remain in as good condition as when first constructed, and that is the corduroy road of olden times. And may Providence deliver us from that.

There is no such thing as a permanent road. They all require constant care and repairs. And the more perfect the road surface the greater will be the care and attention required to keep it smooth. It costs more to properly maintain a stone road than a gravel road. But a good stone road is a better road than a good gravel road.

Some theorists tell us that if we could have all the money that has been expended upon our bad roads we could pave them with gold. Our State has expended $70,000,000 in road repairs in the past forty years. We are told that if this sum had been expended in building permanent roads we would now have a complete system of good roads. They forget that good roads cost as much for maintenance as poorer roads; they forget that if we had expended $70,000,000 in building good roads in 1860, we would still have had to expend another $70,000,000 or more to keep them in good condition to the present time.

Or if, on the other hand, we had saved that $70,000,000 of repairs to now expend in building good roads we should for that forty years have had to get along with roads that would have been ten times worse than the ones we have had. For there is no denying that the expenditures that have been made upon our roads for repairs, although very wasteful and not a complete success, have been nevertheless of great benefit.

To go back to our search for a remedy, permit me to repeat the reasons for bad roads in Indiana:

1. Bad drainage.
2. Repairs delayed.
3. Too much repairing at one time.
4. Too much material, not sufficient labor.
5. Repairs at wrong season.
6. Improper material.
7. Poor location.

1. To secure proper drainage of surface water requires constant attention. All that is necessary is to keep the road crowned, but it must be watched and cared for at all times and especially in wet weather. There must be some one whose duty it is to keep the ruts and chuckholes filled and the ditches clear.

2. Repairs need not be delayed if some one is employed whose duty it is to attend to them promptly, provided there be a superintendent to see that he does his duty.

3. Repairs would not all be made at one time if a single attendant were employed for a long time instead of the present method of many men for a few days.

4. Too much material is used and too little labor, because material is usually cheap and labor is expensive, and because it is easier to tell a man how to haul a load of gravel than to tell him how to make tools for filling the ruts.

5. Place a man in charge of the road who has to attend to it constantly and he will soon learn that it is easier to keep it in good condition by scraping the ruts than by drawing on four times as much gravel as is essential.

6. Improper material is used because the men employed on repairs have neither the time nor the incentive to learn the qualities of road materials. This requires a certain amount of expert knowledge that can easily be gained by experience.

7. To remedy poor location requires only that a man should be able to see that it is easier to draw a load around a hill than over it. Teach the road attendant to ride a wheel and he will soon appreciate the difficulty of steep grades.

In short the reason our roads are bad is because nobody makes it a business to attend to them. And the remedy is a system of maintenance which shall make it somebody's business to keep them in good repair. Dirt roads should be in good condition for at least nine months of the year, and gravel roads ought to be good at all times.

By our present Indiana laws we have abundant provisions for superintendence, not perhaps of the most expert kind, but engineering skill is not necessary. What is more essential in a road superintendent is that he should have the power to discharge an attendant for lack of attention to duty, and that he should be able to tell when a road is not in good condition. As a matter of fact the average engineer is too apt to go to the other extreme and to attempt to construct permanent roads at great expense when our system of maintenance by no means warrants it, which would be as reckless as to invest in an expensive building and then fail to insure it against fire. Our roads should be divided into sections of not more than twenty miles in length; for each section a man and team should be employed, all of whose attention is to be devoted to the care of that road from the first day of March until the first day of December.

He should be employed by the day so that he may be liable to discharge at any time for neglect of duty. He should be selected by competitive bids for day labor of eight hours per day.

Man and team could be secured for nine months' service at the rate of $1.50 or less per day. The rate at present paid by our county commissioners for man and team is $2.50, because they are employed for but a few days at a time. And for this $2.50 a man is secured who takes no interest in the road and who piles on the material because it is easier to draw gravel than to spread it, and because it makes his job last longer.

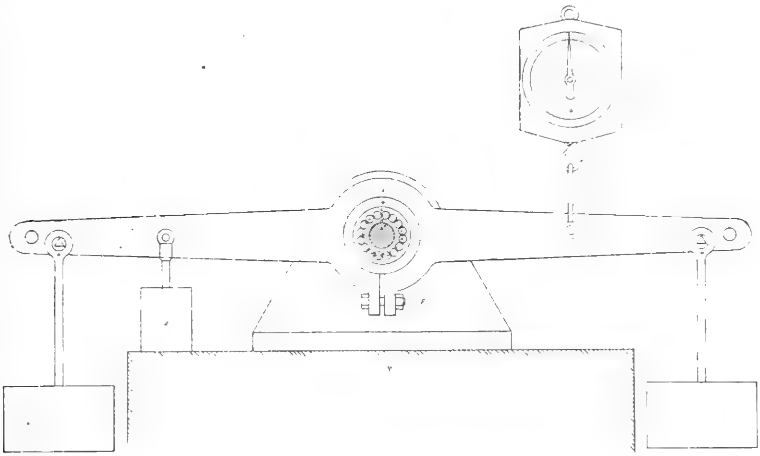
To secure the adoption of such a system for our gravel roads requires only that county commissioners should be convinced that it is more desirable as well as more economical than present methods. They have full powers to act.

For our township roads it requires that all road taxes should be paid in money instead of in day labor as at present. The day-labor system produces the same kind of results that would be secured by a school system if the citizens assessed were permitted to work out their school taxes by taking turns in teaching the public school. When road taxes are paid in money, the division of township roads into sections, and the employment of attendants, will solve the road problem.

This method of maintenance by an attendant who devotes all of his time to the road, is in use in isolated cases in the United States, principally in New York State. In European countries it is acknowledged to be the only satisfactory method of maintenance, and it is the basis of the superb system of highways enjoyed by France and Germany.

Some Tests on Ball Bearings. By M. J. Golden.

These tests were made to determine the amount of power absorbed by ball bearings of the form used in supporting shafting and spindles, when the load is light. The bearing, in this set, was loaded with weights that varied from ten pounds (the weight of the parts) to three hundred pounds, by increments of forty pounds, except the last one; that was ten pounds. The apparatus used is shown in the sketch, where (A) is a spindle that is revolved by means of a belt from a counter-shaft. To this spindle is attached (B), the inner part of the ball race; the outer part of the race being held in a cage (D) that is clamped inside the balanced arm (E). Near the extremities of the balanced lever are inserted knife edges that are on a line drawn through the center of the rotating spindle, and the weights used were suspended from these knife edges, as shown.



A dash-pot (H) was used to check the vibration of the lever; and the tendency of the lever to rotate, due to friction with the revolving spindle, was measured on a scale (G).

The method of operation was to first bring the lever nearly to balance, leaving a slight excess weight on the scale side, then on causing the spindle to rotate there was an additional pull on the scale arm, due to the friction of the moving parts. This additional pull, when reduced to the ball path on the part (c), could be used to find the coefficient of friction.

The following table will show the form of log kept:

BALL-BEARING FOR ONE INCH SHAFT.

(Oil Used.)

No.	Weight on Scale. Ounces.	Weight. Pounds.	Rev. Spindle.	Time. Seconds.	Heat.	Coefficient F.
7	¼	90	256	30	None.......	.0017
8	¼	90	442	30	None.......	.0017
9	⅜	90	757	30	None.......	.0026

BALL-BEARING FOR ONE INCH SHAFT—CONTINUED.

(Oil Used.)

No.	Weight on Scale. Ounces.	Weight. Pounds.	Rev. Spindle.	Time. Seconds.	Heat.	Coefficient F.
10	3/8	130	256	30	None.......	.0018
11	3/8	130	431	30	None.......	.0018
12	3/8	130	758	30	None.......	.0018

Three sets were made for each load, and, with the weights used, the coefficient of friction varied from .0017 to .0022, as averages for the three sets. Of course, the width of this range may be due to inaccuracy in reading from the scale, as the variation in pull on the scale arm caused a rapid vibration of the scale index.

The bearings used were those supplied on the market for carrying shafts, and the principal cause of the jar in the apparatus during the test was due to slight inaccuracies in grinding the races.

In another set of tests, where the load was increased to seven hundred pounds, it was found that somewhere between the six hundred and the seven hundred pounds load the balls and races had become pitted, small pieces of the hardened steel being torn from the surfaces. These pieces were found in the race-way or in the oil that was used. It was found, further, that the tendency to heat was much reduced when oil was used and that the whole movement was smoother and steadier.

Further Studies in the Propagation of Sound. By A. Wilmer Duff.

[Abstract.]

In a previous paper the writer gave a theoretical discussion of the propagation of sound in spherical waves, allowing for the effect of the viscosity of the air and the conduction and radiation of heat from the condensations and to the rarefactions. It resulted from this investiga-

tion that at short distances from the source the intensity of the sound varies as

$$\frac{1}{r^2}\left(1+\frac{a^2}{n^2 r^2}\right),$$

while at great distances from the source the intensity varies as

$$\frac{e^{-2mr}}{r^2}.$$

In these formulæ r stands for the distance from the source, a for the velocity of sound, and n for the number of vibrations per second, while m is a constant that depends on viscosity conduction and radiation.

In the previous paper the author described experiments made to find the value of m. The method was confessedly not altogether satisfactory. Later another method was devised and applied during the summer of 1898. As before, the work was performed in the open air at a very quiet part of the River St. John, New Brunswick, Canada. The season was very unfavorable, and only the few results hereafter described were obtained.

The greatest difficulty in such work is in finding a variable standard of intensity of the same pitch and quality as the sound studied. In the present case this was overcome by using the sound conveyed through a telephone as the standard, the transmitter being placed near the source of sound and the receiver held at such a distance from the ear that the sound heard directly and that heard through the telephone were of equal intensity. Only one ear was used, the other being filled with wool and closely covered by a heavy pad. This use of a telephone receiver at different distances from the ear as a standard implied a knowledge of the law of intensity of the sound at different distances from the receiver. This point, the law of intensity at short distances, was first tested by using the receiver in two states of intrinsic sensitiveness—first, shunted; second, not shunted. Now, if a series of sounds of different intensities (e. g., the sound of the same whistle differently deadened by coverings) be compared with these two standards, the ratio of the two intensities thus estimated for each sound should be the same for all the sounds, and if calculation according to the theoretical law above stated for short distances should show such a constancy of ratio, it would afford strong evidence that the theoretical law is correct. The tables of results obtained verified the law of intensity at short distances and showed that the commonly accepted law of inverse squares at short distances is quite inapplicable.

Having thus verified the theoretical law for short distances, the use of the telephone receiver as a standard for estimating the intensity at great distances from the source becomes possible.

Tables of results summarizing the observations obtained at great distances showed that the values of m required to reconcile the observed variations of intensity at each increase of distance with the theoretical law at great distances increased uniformly; and hence it is evident that the theoretical law can not be quite correct. In fact, there must be another cause of decay of intensity not taken account of in the theoretical discussion; and this other cause, whatever it is, produces results not in accord with an exponential law of variation. What this other cause is, the author does not undertake to say.

The Intensity of Telephonic Sounds. By A. Wilmer Duff.

[Abstract.]

If a sound of constant intensity act on a telephone transmitter, the intensity of the sound given off from the receiver will depend upon the total resistance, inductive and non-inductive, of the circuit. If the circuit include a resistance box and the total resistance be varied in a known way, the relative changes of current affecting the receiver can be calculated. If, now, the receiver be held at varying distances from the ear, so that the sound emitted by it seems to the ear as loud as the sound heard directly from the distant source that acts upon the transmitter, then the variations in intensity of the sound given off by the receiver can also be estimated. (See preceding article.)

By this method it was found that the intensity of sound emitted by the receiver varied roughly as the three-halves power of the current traversing the circuit.

The Distance to Which Small Disturbances Agitate a Liquid.

By A. Wilmer Duff.

[Abstract.]

In the course of an unfinished piece of work on a new method for determining the viscosity of water, the following somewhat curious result was obtained:

If a sphere of one centimeter radius hang from an arm of a balance by a long fine wire, and be immersed in a vessel of water, it may be caused to perform vertical vibrations of any desired extent and rapidity by suitably weighting the pans of the balance. The nearness of the sides of the vessel will be found to greatly affect the rate at which the vibrations die down. Even when the sides of the vessel are very distant, they have an appreciable effect. When the vessel is a large-sized carboy, the effect of the sides is still quite appreciable. That is to say, if a sphere of one centimeter radius perform one vibration for every fifteen seconds through a range of one centimeter in a mass of water, the effect on the water at a distance of a foot from the sphere is quite appreciable and measurable, the water being agitated to that distance instead of merely flowing round the slowly moving sphere to fill up the space it vacates.

It may be added that the method referred to for measuring the viscosity of water is not intended as a practical method for finding the viscosity of different liquids, but merely as a means of contributing to the settlement of the dispute regarding the discordant values of the viscosity of water obtained by the several other methods that have been employed.

The Evaporation of Water Covered by a Film of Oil.

By A. Wilmer Duff.

[Abstract.]

A vessel of water covered by a film of paraffin oil 4 mm. thick and placed in a box artificially kept dry, lost 4 gms. of water in two months, while in another case in which the film of oil was only 1 mm. thick the loss in two months was 11 gms. After considerable difficulty it was proven that this loss was not at all due to a passage of the water through

the oil film, but to the water creeping out between the oil and the glass. This may be tested by placing two similar glass vessels on the pans of a sensitive balance, pouring some water in one and covering it with a layer of oil, and pouring in the other oil only to the same depth. After counterbalancing and closing the balance case very tightly to prevent air currents, the arms may be kept counterbalanced by suitable riders, and it will be found that the evaporation of the water takes place with sufficient rapidity to be measured in a short time. But if the water be contained in a watch-glass placed in the bottom of the glass vessel and entirely covered and surrounded by oil, no evaporation will be discovered.

To indicate the rate at which water can thus creep between oil and glass, it may be stated that when the glass vessel is 9 cm. in diameter and the layer of oil as much as ½ cm. thick, the evaporation takes place at the rate of nearly a milligram per hour.

A Note on Temperature Coefficient of Electrical Conductivity of Electrolytes. By Arthur Kendrick.

[Abstract.]

This paper was a preliminary note of work begun to determine the temperature coefficient of conductivity of various electrolytes of varying concentrations. The two plates give the curve of resistance and molecular conductivity in the case of a $\frac{2}{100}$ normal KCl aqueous solution and an approximately $\frac{1}{100}$ normal KCl aqueous solution, between 0° C and about 50°. The figures 0.100 and 0.200 mark the ordinates of the molecular conductivity curves. The resistances in each case are the actual, corrected resistances for the cell used, and the molecular conductivity is the resistance, taken from the curve divided by $\frac{2}{100}$ and $\frac{1}{100}$ respectively, the concentration values. The broken straight lines are drawn to make noticeable the curvature.

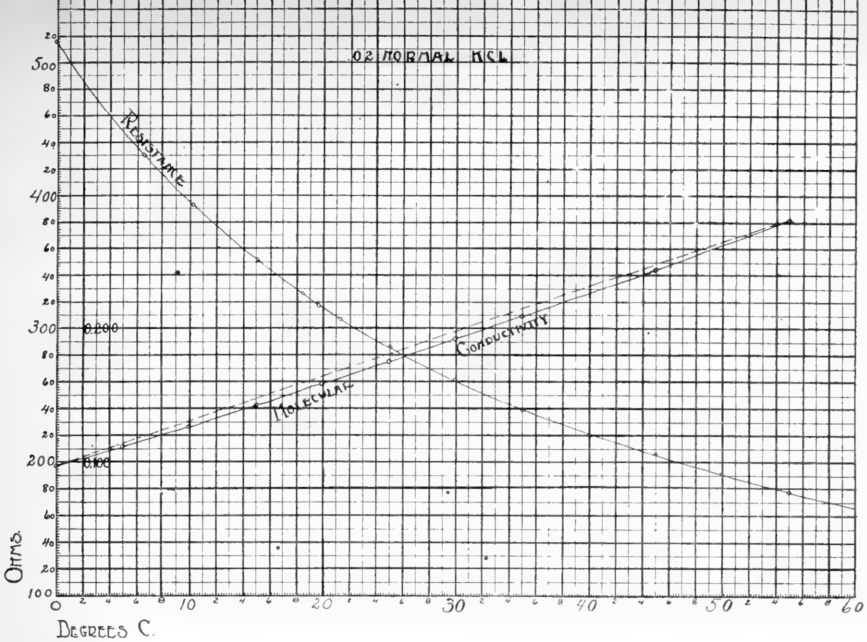
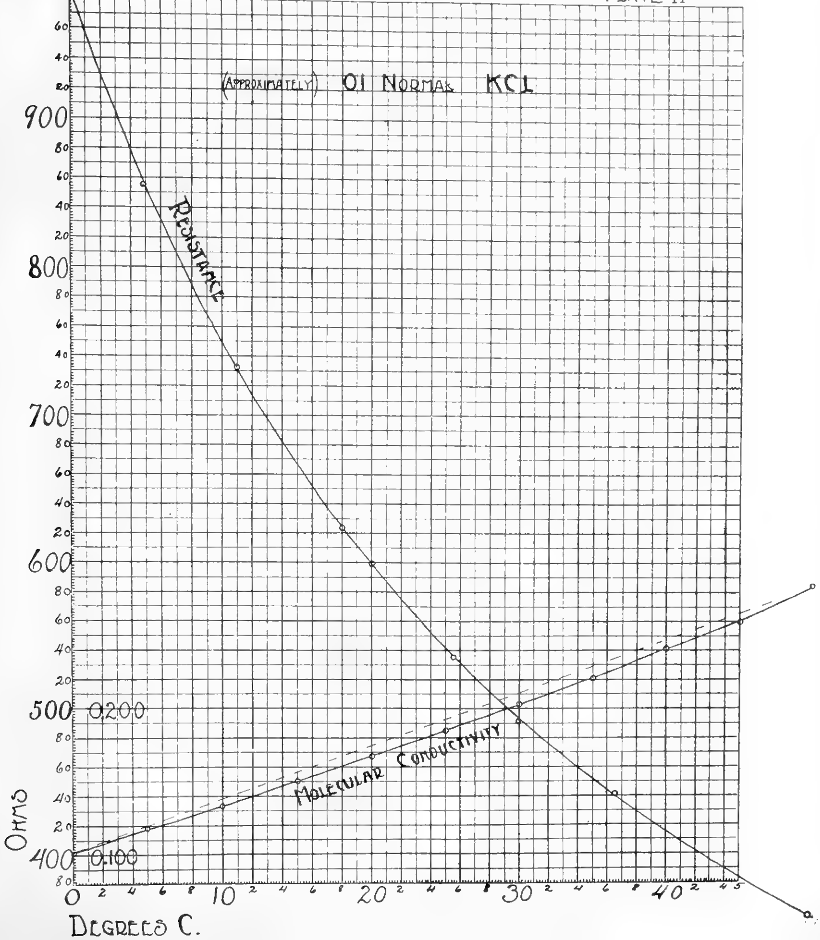

.02 NORMAL KCL
RESISTANCE
MOLECULAR CONDUCTIVITY
0.200
0.100
OHMS
DEGREES C.

PLATE II


(APPROXIMATELY) .01 NORMAL KCL
RESISTANCE
MOLECULAR CONDUCTIVITY
0.200
0.100
OHMS
DEGREES C.

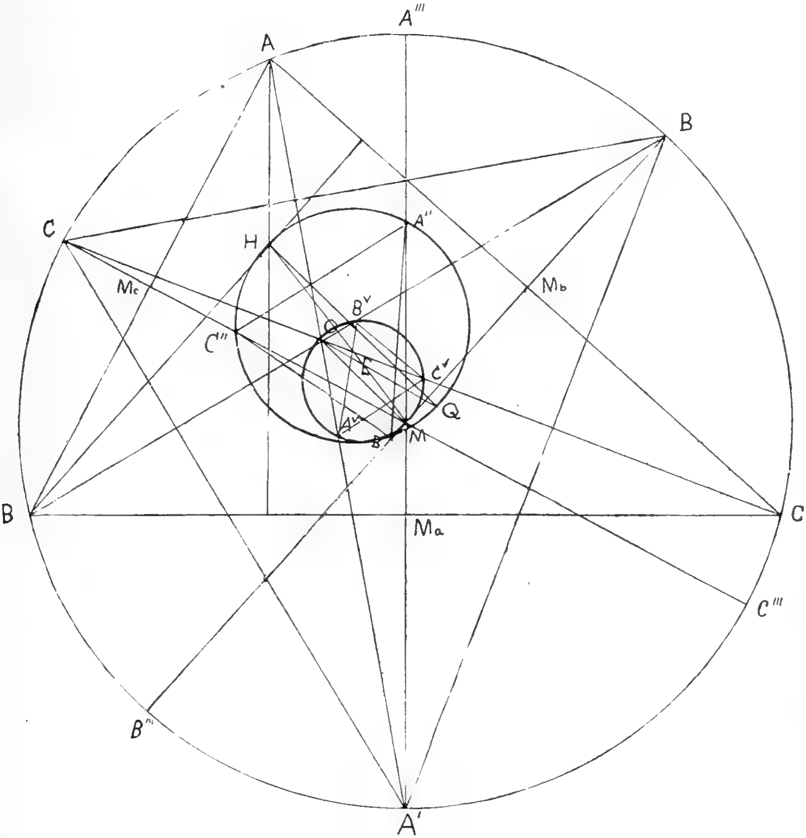
A Common Text-Book Error in the Theory of Envelopes.

By A. S. Hathaway.

The cause of this communication is the recent appearance of several text-books on the calculus that embody an error in the theory of envelopes that dates at least as far back as Todhunter's calculus, and is now reproduced in all text-books under the impression, apparently, that it has acquired the sanction of authority, although Cayley pointed out the error nearly forty years ago, while the subject matter is presented in all text-books on Differential Equations in its correct form. The error consists in defining the envelope of a moving curve as the locus of its self-intersections, and then proving that the envelope touches the moving curve in every position—i. e., proving as true that which is often false—for the locus of self-intersections of a moving curve may cut the curve at any angle, as at right angles, wherever the two meet. A simple example is the curve $(y-m)^2=(x-3)^3$, whose locus of self-intersections, as m varies, is the straight line $x=3$, which cuts every curve of the given system at right angles. The fact is, that the envelope should be *defined* as the curve that touches every curve of a given system. It can then be shown it is *a* locus of self-intersections of the curves of the system, provided such self-intersections are not the singular points of the given system. The locus of such singular points is always a locus of self-intersections, but it is not in general an envelope of the system, and may cut every curve of the system at any constant or varying angle. The text-book blunder referred to is of the same logical character as would be the attempt to prove that a quadruped is a horse. To be sure, a horse is a quadruped, but not every quadruped is a horse. Thus a curve that touches every curve of a given system is a locus of self-intersections of the system, but not every locus of self-intersections of the system will touch every curve of the system. The error in the proof arises out of the assumption that if two points of a curve approach coincidence, the limiting position of the chord joining the two points is a tangent line at the point of coincidence. This is all right if the point of coincidence is not a singular point of the curve. But at a singular point, as a sharp point like the bottom of a letter V, the limiting position of two points that approach the point on opposite sides is absolutely indeterminate, and is not necessarily a tangent line at that point.

A NEW TRIANGLE AND SOME OF ITS PROPERTIES. BY ROBERT JUDSON ALEY.

Explanation of Figure. — ABC is any triangle, of which M is the circumcenter, O the incenter, H the orthocenter, and Q Nagel's Point. $A'A'''$, $B'B'''$ and $C'C'''$ are diameters perpendicular to the sides BC, CA, AB, respectively.



I. If A^v, B^v, C^v are the middle points of AA', BB', CC', respectively, then OM is the diameter of the circumcircle of $A^v B^v C^v$.

Since A^v is the middle point of AA',

MA^v is parallel to AA'''.

But AA''' is perpendicular to AA',

$\therefore$ MA^v is perpendicular to AA'.

Hence $MA^{v}O$ is a right angle.

Similarly $MB^{v}O$, and $MC^{v}O$ are right angles.

$\therefore$ a circle upon OM as diameter will pass through A^{v}, B^{v}, C^{v}.

II. The triangle $A^{v}B^{v}C^{v}$ is similar to Nagel's triangle $A''B''C''$.

$\angle B^{v}C^{v}A^{v}$ is the supplement $\angle B^{v}OA^{v}$.

$$\angle B^{v}OA^{v} = \angle AOB.$$
$$= \pi - (\tfrac{1}{2}A + \tfrac{1}{2}B).$$
$$= A + B + C - \tfrac{1}{2}(A + B).$$
$$= C + \tfrac{1}{2}(A + B).$$
$$\pi - \angle B^{v}OA^{v} = \pi - [C + \tfrac{1}{2}(A + B)].$$
$$= A + B + C - [C + \tfrac{1}{2}(A + B)].$$
$$= \tfrac{1}{2}(A + B).$$
$$\therefore B^{v}C^{v}A^{v} = \tfrac{1}{2}(A + B).$$

MA^{v} is perpendicular to AA'.

MC^{v} is perpendicular to CC'.

$$\angle (MA^{v}, MC^{v}) = \angle (AA', CC').$$
$$i.\ e.,\ \angle A^{v}MC^{v} = A'OC.$$
$$= \tfrac{1}{2}(A + C).$$

But $\angle A^{v}MC^{v} = A^{v}B^{v}C^{v}$.

$\therefore \angle A^{v}B^{v}C^{v} = \tfrac{1}{2}(A + C.)$

Similarly $\angle B^{v}A^{v}C^{v} = \tfrac{1}{2}(B + C)$.

The angles of the triangle $A''B''C''$ (Nagel's triangle) are $\tfrac{1}{2}$ (B + C), $\tfrac{1}{2}(A + C)$, $\tfrac{1}{2}(A + B)$, respectively. (Schwatt's Geometric Treatment of Curves, page 39.)

$\therefore$ $A^{v}B^{v}C^{v}$ is similar to $A''B''C''$. It is also similar to $A'B'C'$, for $A'B'C'$ and $A''B''C''$ are similar.

III. O is the centre of perspective of $A^{v}B^{v}C^{v}$ and $A'B'C'$.

IV. E, the centroid of ABC, is the internal center of similitude of the circumscribing circles of $A''B''C''$ and $A^{v}B^{v}C^{v}$.

OM is parallel to HQ.

It is known that H, E, M, are collinear, as are also O, E, Q.

$\therefore$ HM and OQ intersect at E.

$\therefore$ E is the internal center of similitude.

V. E is also the center of perspective of $A^{v}B^{v}C^{v}$ and $A''B''C''$.

For, consider the triangle $AA''A'$.

$A''A^{v}$ is a median and so is AM_a.

$\therefore$ $A''A^{v}$ passes through E.

Now consider the triangle $BB''B'$.

$B''B^v$ is a median and so is BM_b.

$\therefore$ $B''B^v$ passes through E.

In the same way we can show that $C''C^v$ also passes through E.

$\therefore$ E is the center of perspective of $A''B''C''$ and $A^vB^vC^v$.

VI. All the lines in $A^vB^vC^v$ are just one-half the corresponding lines in $A''B''C''$.

This is an immediate consequence of the fact $OM = \frac{1}{2} HQ$. (Schwatt, Geomet. Curves, page 40.)

VII. The sides of the triangle $A^vB^vC^v$ are oppositely parallel to the corresponding sides of $A''B''C''$, *i. e.*, A^vB^v is parallel to $B''A''$, etc.

OM is parallel to HQ.

HA'' is perpendicular to AA'.

MA^v is perpendicular to AA'.

$\therefore \angle A''HQ = \angle OMA^v$.

In the same way

$\angle B''HQ = \angle OMB^v$.

$\angle C''HQ = \angle OMC^v$.

This shows that the points A^v, B^v, C^v are located with respect to O, just as A'', B'', C'' are located with respect to Q.

$\angle (OM, B^vA^v)$ is measured by $\frac{1}{2}$ (arc OB^v + arc A^vC^v + arc C^vM).

$\angle (HQ, A''B'')$ is measured by $\frac{1}{2}$ (arc $B''Q$ + arc $A''C''$ + arc $C''H$).

But arc OB^v measures the same angle in the circle on OM as diameter, that the arc $B''Q$ measures in the circle on HQ as diameter.

The same is also true of the arcs A^vC^v and $A''C''$, and C^vM and $C''H$.

$\therefore \angle (OM, B^vA^v) = \angle (HQ, A''B'')$.

But since OM is parallel to HQ, we have at once $A''B''$ parallel to B^vA^v.

In the same way we may prove that $B''C''$ is parallel to C^vB^v and $C''A''$ parallel to A^vC^v.

$\therefore$ the sides of $A^vB^vC^v$ are oppositely parallel to the corresponding sides of $A''B''C''$.

VIII. The triangle $A^vB^vC^v$ is Nagel's triangle for the triangle $M_aM_bM_c$.

It is known (Schwatt, page 41) that O is Nagel's point in the triangle $M_aM_bM_c$, and that M is the orthocenter. The circle on OM as diameter is Nagel's circle for the triangle $M_aM_bM_c$. We know that the sides of $M_aM_bM_c$ are oppositely parallel to the sides of ABC, and we have proven that $A^vB^vC^v$, inscribed in the Nagel's circle of $M_aM_bM_c$, has its sides oppositely parallel to the sides of Nagel's triangle for ABC.

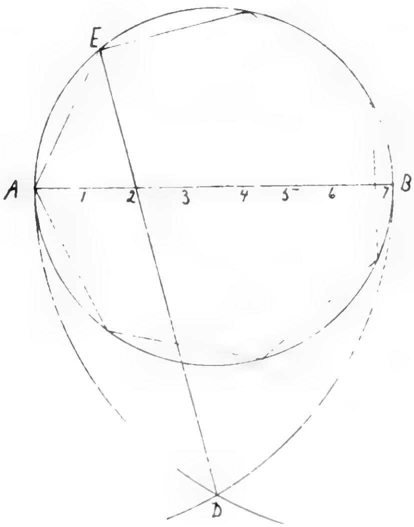
$\therefore$ $A^vB^vC^v$ is Nagel's triangle for $M_aM_bM_c$.

Note on Angel's Method of Inscribing Regular Polygons.

By Robert Judson Aley.

On page 47, "Practical Plane and Solid Geometry," by Henry Angel, the following method of inscribing a regular polygon in a circle is given:

"Let ACB be the given circle, and let the required figure be a heptagon. Draw the diameter AB, and divide it into seven equal parts. (The number of parts is regulated by the required number of sides.) With A and B as centers—radius AB—describe two arcs intersecting in D. From D draw the line D 2, passing through the second division of the diameter, and produce it, to meet the circle in E. The distance, AE, will divide the circle into seven equal parts; and if the points of division be joined, a heptagon will be inscribed in the circle."



The method has the merit of seeming to succeed. When applied to circles of short radii, no noticeable error is found in the drawing. I have not attempted to give a geometric demonstration of the error which arises in this and all similar rule of thumb methods of inscribing regular polygons. Let the diameter AB, for convenience, be fourteen units in length; then, by obvious trigonometric processes, we find AE to be 6.09212 units in length, while in a true heptagon the side would be 6.07436 units long.

Take a circle whose diameter is thirty-six units; Angel's method makes the side of a 36-gon equal to 3.33982 units, while the true length is 3.13776 units. The larger number of sides makes the error of the method more apparent.

Concurrent Sets of Three Lines Connected with the Triangle.

By Robert Judson Aley.

To the student of the pure geometry of the triangle, few subjects are more interesting than the concurrency of lines. The following collection of concurrent sets of three lines has been made in the hope that it may prove of value to geometric students. No claim is made to completeness. The list is as complete as the author could make it with the material to which he had access. Many of the notes, and a large number of the propositions have been taken from the published papers of Dr. J. S. Mackay, of Edinburgh, perhaps the foremost student of the geometry of the triangle. No classification of the propositions seems possible and so none has been attempted.

1. The median lines of a triangle are concurrent. The point of concurrency, usually denoted by G, is called the *median point* or centroid.

2. The in-symmedian lines of a triangle are concurrent. The point of concurrency is called the symmedian point or Grebe's point, and is generally denoted by K. (For a history of this point, see J. S. Mackay, in Proceedings of Edinburgh Mathematical Society, Vol. XI.)

3. The altitudes of a triangle are concurrent. The point of concurrency, usually denoted by H, is called the ortho centre. (This proposition occurs in Archimedes's Lemmas and in Pappus's Mathematical Collection.)

4. The internal angle bisectors of a triangle are concurrent. The point of concurrency is the center of the inscribed circle and is usually denoted by I. (Euclid IV, 4.)

5. The internal bisector of any angle of a triangle and the external bisectors of the other two angles of the triangle are concurrent. The points of concurrency, denoted by I_1, I_2, I_3 are the centers of the three escribed circles.

6. The perpendiculars to the sides of a triangle at the midpoints of the sides concur at the center of the circumscribed circle. This point of concurrence is usually denoted by O. (Euclid.)

7. Lines drawn from the vertices to the points of contact of the in-circle with the opposite sides are concurrent. (The point of concurrency, Γ, is called the Gergonne Point. It was named by J. Neuberg after J. D. Gergonne.)

8. Lines drawn from the vertices to the points of contact of the escribed circles with the opposite sides concur at Q, Nagel's Point. (For a number of interesting properties of this point, see Schwatt's "Geometric Treatment of Curves.")

9. Lines drawn from the vertices making equal angles with the sides AB, BC, CA, respectively, concur at Ω and Ω', the two Brocard points of the triangle.

10. If A_1, B_1, C_1, is Brocard's first triangle, then AA_1, BB_1, CC_1, concur at D, the point isotomic conjugate to K.

11. If L, M, N, be the midpoints of the sides of the triangle ABC, and L', M', N' the midpoints of the sides of the triangle $A_1B_1C_1$, then LL', MM' and NN' concur at S.

12. AL', BM', and CN' concur at S'. S and S' are isogonal conjugate points. (Schwatt's "Geometric Treatment of Curves," p. 5.)

13. Perpendiculars from A, B, C upon B_1C_1, C_1A_1, A_1B_1, respectively, concur at N, a point on the circumcircle of the triangle ABC, known as *Tarry's Point.*

14. Lines through A, B, C, parallel to B_1C_1, C_1A_1, A_1B_1, respectively, concur at a point on the circumcircle of the triangle ABC known as *Steiner's Point.*

15. Parallels to AB and CA through C and B, respectively, concur with the median through A. There are evidently three such points of concurrency. These points are sometimes called the *external median points.*

16. If three lines through the vertices are concurrent, their isogonal conjugates with respect to the angles of the triangle are also concurrent. (Steiner's Gesammelte Werke I., 193, 1881.) If the ratios of the distances of the first point from the sides are $l : m : n$, those of the second point are

$$\frac{1}{l} : \frac{1}{m} : \frac{1}{n}.$$

17. Perpendiculars to the sides of the triangle ABC from the midpoints of the sides of the orthic triangle of ABC are concurrent. (Edouard Lucas in Nouvelle Correspondance Mathématique II, 95, 218, 1876.)

18. The ex-symmedians from any two vertices and the in-symmedian from the third vertex are concurrent. There are evidently three such points of concurrency. They are sometimes called the *external symmedian points.*

19. If three lines drawn from the vertices of a triangle to intersect the opposite sides are concurrent, the lines isotomic conjugate to them are also concurrent. If the ratios of the distances of the first point of concurrency from the sides are $l : m : n$, the ratios of the second point are

$$\frac{1}{a^2l} : \frac{1}{b^2m} : \frac{1}{c^2n}.$$

20. If the three perpendiculars from the vertices of one triangle upon the sides of another triangle are concurrent, then the three perpendiculars from the vertices of the latter upon the sides of the former are also concurrent. (Steiner, Gesammelte Werke I., 157, 1881.) (Lemoine calls such triangles *orthologous* and the points of concurrency *centers of orthology.*

21. Brocard's Triangle and ABC are orthologous. Perpendiculars from A_1, B_1, C_1, upon BC, CA, AB, respectively, are concurrent. (See No. 13.)

22. If three points be taken on the sides of a triangle such that the sums of the squares of the alternate segments taken cyclically are equal, the perpendiculars to the sides of the triangle at these points are concurrent. (T. G. de Oppel, "Analysis Triangulorum," p. 32, 1746.)

23. If on the sides of a triangle ABC, equilateral triangles LBC, MCA, NAB be described externally, AL, BM, CN are equal and concurrent.

24. If on the sides of a triangle ABC, equilateral triangles $L'BC$, $M'CA$, $N'AB$ be described internally, AL', BM' CN' are equal and concurrent. (Dr. J. S. Mackay gives 24 in Vol. XV of Proceedings of Edinburgh Mathematical Society and attributes 23 to T. S. Davies in Gentleman's Diary for 1830, p. 36.)

25. If $A''B''C''$ be Nagel's triangle, then perpendiculars from A, B, and C upon $B''C''$, $C''A''$, $A''B''$, respectively, are concurrent.

26. Perpendiculars from A'', B'', C'' upon BC, CA, AB, respectively, are concurrent.

27. If A', B', C' be the midpoints of the arcs subtended by BC, CA, AB, respectively, then perpendiculars from A', B', C' upon $B''C''$, $C''A''$, $A''B''$, respectively, are concurrent.

28. Perpendiculars from A'', B'', C'' upon $B'C'$, $C'A'$, $A'B'$, respectively, are concurrent.

29. If distances equal to $2r$ (diameter of the inscribed circle) be laid off from the vertices on each of the altitudes, three points A^{iv}, B^{iv}, C^{iv} are obtained. Perpendiculars from A, B, C upon $B^{iv}C^{iv}$, $C^{iv}A^{iv}$, $A^{iv}B^{iv}$, respectively, are concurrent.

30. Perpendiculars from A^{iv}, B^{iv}, C^{iv} upon BC, CA, AB, respectively, are concurrent. (Nos. 25, 27 and 29 are given in Schwatt's "Geometric Treatment of Curves," pages 40, 43 and 44. Nos. 26, 28 and 30 are direct consequences of the orthologous relation of the triangles. See No. 20.)

31. The perpendiculars from the middle points of the sides of Brocard's first triangle upon the corresponding sides of the triangle ABC are concurrent.

32. The lines joining the middle points of the sides of a triangle with those of the segments towards the angles of the corresponding altitudes meet in a point and bisect each other.

33. The straight lines which join the midpoint of each side of a triangle to the midpoint of the corresponding altitude concur at the *symmedian point.* (Dr. F. Wetzig in Schlömlich's Zeitschrift, XII, 289.)

34. If two sides of a triangle are divided proportionally the straight lines drawn from the points of section to the opposite vertices, will intersect on the median from the third vertex.

35. Every two perpendiculars to the sides of a triangle at points of contact of escribed circles external to the same vertex are concurrent with the perpendicular to the opposite side at the point of contact of the inscribed circle. There will be three such points of concurrency.

36. If the three sides of a triangle be reflected with respect to any line, the three lines through the vertices parallel to the reflexions of the opposite sides are concurrent.

37. The vertices of ABC are joined to a point O, and a triangle $A'B'C'$ is constructed having its sides parallel to AO, BO, CO respectively. Lines through A', B', C' parallel to the corresponding sides of the triangle ABC are concurrent.

38. If XYZ be any transversal of the triangle ABC, and if AX, BY, CZ form the triangle PQR, then AP, BQ, and CR are concurrent.

39. If D, E, F be the feet of the altitudes, then the lines connecting A, B, C to the middle points of EF, FD, DE, respectively, concur at the symmedian point.

40. The perpendiculars from A, B, C upon EF, FD, DE are concurrent.

41. Through the vertices of the triangle ABC lines parallel to the opposite sides are drawn, meeting the circumcircle in A', B', C'. $B'C'$, $C'A'$, $A'B'$ meet BC, CA, AB in P, Q, R, respectively. AP, BQ, CR are concurrent.

42. With the same notation as 41, $A'P$, $B'Q$, $C'R$ are concurrent. (41 and 42 occur in St. John's College Questions, 1890.)

43. Three circles are drawn each touching two sides of the triangle ABC and the circumcircle internally. The points of contact with the circumcircle are L, M, N, respectively. AL, BM, CN are concurrent.

44. If in 43 the circles touch the circumcircle externally in L', M', N', then $L'A$, $M'B$, $N'C$ are concurrent. (43 and 44 are given by Professor de Longchamps, Ed. Times, July, 1890.)

45. If a circle touch the sides of the triangle ABC in X, Y, Z, then the lines joining the middle points of BC, CA, AB to the middle points of AX, BY, CZ, respectively, are concurrent.

46. If a circle cut the sides of the triangle ABC in X, X'; Y, Y'; Z, Z'; if AX, BY, CZ are concurrent, so also are AX', BY', CZ'.

47. If X, Y, Z be three points on the sides of the triangle ABC such that the pencil $D(AC, EF)$ is harmonic, then AD, BE, CF are concurrent.

48. If tangents to the circumcircle at the vertices of the triangle ABC, meet in L, M, N, then AL, BM and CN are concurrent.

49. If on the sides of the triangle ABC, similar isosceles triangles LBC, MCA, NAB be described, AL, BM, CN are concurrent.

50. If the ex-circles touch the sides to which they correspond in D_1, E_2, F_3, the perpendiculars to the sides through these points are concurrent.

51. If D, E, F are the points of contact of the incircle with the sides of the triangle ABC and if DI, EI, FI meet EF, FD, DE in L, M, N, respectively, then AL, BM, CN concur.

52. If DD', EE', FF' are diameters of the incircle through D, E, F, the points of contact with the sides of the triangle ABC, then AD', BE', CF' concur.

53. If P, Q, R be collinear points in the sides BC, CA, AB of the triangle ABC, and if P', Q' R' be their harmonic conjugates with respect to those sides then AP', BQ', CR' are concurrent.

54. If squares $APQB$, $BUVC$, $CXYA$ be described upon the sides of the triangle ABC (all externally or all internally) and if QP meet XY in α, PQ meet VU in β, UV meet YX in γ, then αA, βB, γC concur in K the symmedian point. (Halsted, "El. Synthetic Geometry," p. 150.)

55. $A'B'C'$ is the pedal triangle of Ω, and $A''B''C''$ is the pedal triangle of Ω'. $B''C'$, $C''A'$, $A''B'$ form the triangle XYZ, whose sides are parallel to the sides of ABC. PQR is *the* pedal triangle of ABC. PX, QY, RZ concur at the circumcenter of XYZ.

56. The Simson lines of the median triangle LMN of the triangle ABC, with respect to the vertices P, Q, R of the pedal triangle, concur at the center of Taylor's circle.

57. The Simson lines of the pedal triangle PQR of the triangle ABC, with respect to the vertices L, M, N of the median triangle concur at the center of Taylor's circle.

58. If BW, CV be perpendicular to BC; CU, AW perpendicular to CA; AV, BU perpendicular to AB; then AU, BV, CW concur at the circumcenter of ABC. (C. F. A. Jacobi, "De Triangulorum Rectilineorum Proprietatibus," p. 56.)

59. If triangles $A_1B_1C_1$ and $A_2B_2C_2$ are circumscribed about the triangle ABC in such a manner that their sides are perpendicular to those of ABC, then A_1A_2, B_1B_2, C_1C_2 concur at the circumcenter of ABC. (Probably known

by Jacobi, but not explicitly stated by him. Lemoine stated it in 1873 to the Association Française pour l'Avancement des Sciences.)

60. When three lines through the vertices of a triangle are concurrent, the six bisectors of the three angles they determine intersect with the corresponding sides of the triangle at six points, every three of which on different sides connect concurrently with the opposite vertices if an odd number of them is internal.

61. When three points on the sides of a triangle are collinear, the six bisections of the three segments they determine connect with the corresponding vertices of the triangle by six lines, every three of which through different vertices are concurrent if an odd number of them is internal.

62. When three points on the sides of a triangle are collinear, their three lines of connection with the opposite vertices determine an exscribed triangle whose vertices connect concurrently with those of the original to which they correspond.

63. H_1, H_2, H_3 are points of intersection of AI, BI, CI, respectively, with the inscribed circle. The perpendiculars from H_1, H_2, H_3 upon BC, CA, AB, respectively, are concurrent.

64. The twelve radii from the incenter and the excenters of a triangle, perpendicular to the sides of the triangle, meet by threes in four points which are the circumcenters of the triangles $I_1 I_2 I_3$, $I I_3 I_2$, $I_3 I I_1$, $I_2 I_1 I$. (I, I_1, I_2, I_3 are the incenter and excenters. See note, p. 99, Vol. I, Proceedings Edinburgh Math. Soc., Dr. Mackay).

65. D, E, F are points of contact of I-circle with the sides of the triangle ABC, D_1, E_1, F_1 points of contact of I_1-circle with sides, D_2, E_2, F_2, of I_2-circle, D_3, E_3, F_3 of I_3-circle.

AD_1, BE_1, CF_1 concur at Γ_1

AD_2, BE_2, CF_2 concur at Γ_2

AD_3, BE_3, CF_3 concur at Γ_3

The points Γ_1, Γ_2, Γ_3 are called the associated Gergonne points. See No. 7.

66. AD_1, BE_3, CF_2 concur at Q_1

AD_3, BE_1, CF_1 concur at Q_2

AD_2, BE_1, CF concur at Q_3

Q_1, Q_2, Q_3, together with Q given in No. 8, are called the Nagel points.

67. AQ, BQ_3, CQ_2 concur at Γ_1.

AQ_3, BQ, CQ_1 concur at Γ_2.

AQ_2, BQ_1, CQ concur at Γ_3.

68. $A\Gamma$, $B\Gamma_3$, $C\Gamma_2$ concur at Q_1.
$A\Gamma_3$, $B\Gamma$, $C\Gamma_1$ concur at Q_2.
$A\Gamma_2$, $B\Gamma_1$, $C\Gamma$ concur at Q_3.

69. AB, DE, D_2E_1 concur at x.
BC, EF, E_3F_2 concur at y.
CA, FD, F_1D_3 concur at z.
x, y, z lie on a line n, say.

70. AB, D_1E_2, D_3E_3 concur at x_1.
BC, E_2F_3, E_1F_1 concur at y_1.
CA, F_3D_1, F_2D_2 concur at z_1.
x_1, y_1, z_1 lie on a line p.

71. AB, NP, I_1I_2 concur at x_2.
BC, PQ, I_2I_3 concur at y_2.
CA, QN, I_3I_1 concur at z_2.
(N, P, Q are the feet of the interior angle bisectors.)
x_2, y_2, z_2 lie on a line q.

72. The three lines n, p, q are concurrent.

73. A', B', C' are the midpoints of the sides of the triangle ABC. Lines drawn through A', B', C', respectively, parallel to the triads of angular transversals which determine Γ, Γ_1, Γ_2, Γ_3, concur at Γ', Γ_1', Γ_2' Γ_3'. Then $\Gamma\Gamma'$, $\Gamma_1\Gamma_1'$, $\Gamma_2\Gamma_2'$, $\Gamma_3\Gamma_3'$ are concurrent at the centroid of the triangle ABC.

74. $I\Gamma'$, $I_1\Gamma_1'$, $I_2\Gamma_2'$, $I_3\Gamma'_3$ concur at the symmedian point of the triangle ABC.

75. IQ, I_1Q_1, I_2Q_2, I_3Q_3 concur at the centroid of the triangle ABC.

(The propositions 65 to 75 inclusive are taken from Mackay's "Euclid" and his "Symmedians and Concomitant Circles.")

76. If DEF be the triangle formed by joining the inscribed points of contact of the triangle ABC; $D_1E_1F_1$ the triangle formed by joining the inscribed points of contact of the triangle DEF; $D_2E_2F_2$ the triangle formed by joining the inscribed points of contact of the triangle $D_1E_1F_1$; I, I_1, I_2, I_3 are the inscribed and escribed centres. I_1D, I_2E, I_3F concur at the homothetic centres of the triangles DEF and $I_1I_2I_3$. ID_1, I_3E_1, I_2F_1 concur at the homothetic centre of the triangles $D_1E_1F_1$ and II_3I_2, and so on. (Dr. Mackay, Proceedings Edinburgh Math. Soc., Vol. I, pp. 51–2.)

77. If three straight lines drawn from the vertices of a triangle are concurrent, the three lines drawn parallel to them from the midpoints of the opposite sides are also concurrent; and the straight line joining the two points of concurrency passes through the centroid of the triangle and is there trisected. (Frigier in Gergonne's Annales, Vol. VII, 170.)

78. If ABC be any triangle and O any point whatever, and A_1, B_1, C_1 be points symmetrical to O with respect to the midpoints of BC, CA, AB, then AA_1, BB_1, CC_1 concur at a point P. The centroid G lies on the line OP and divides it in a constant ratio. (M. d'Ocagne in Nouvelles Annales, Third Series I, 239.)

79. If through K (Grebe's Point) parallels to the sides BC, CA, AB of the triangle ABC are drawn, meeting these sides in D, D'; E, E'; F, F', respectively, and if EF and $E'F'$ intersect in p; FD and $F'D'$ in q; DE and $D'E'$ in r, then Ap, Bq, Cr are concurrent. (Dr. Mackay, "Symmedians of the Triangle," etc., p. 39.)

80. A', B', C' are the midpoints of the sides of the triangle ABC, and I, I_1, I_2, I_3, are the in and ex centers.

I_1A', I_2B', I_3C' concur at the symmedian point of the triangle $I_1I_2I_3$.

IA', I_3B', I_2C' concur at the symmedian point of the triangle II_3I_2.

I_3A', IB', I_1C' concur at the symmedian point of the triangle I_3II_1.

I_2A, I_1B', IC' concur at the symmedian point of the triangle I_2I_1I.

81. If AK, BK, CK cut the sides of the triangle ABC at the points R, S, T and the circumcircle of the triangle ABC at the points D, E, F, then

AK, BF, CE are concurrent.

BK, CD, AT are concurrent.

CK, AE, BD are concurrent.

82. X, Y, Z are the feet of the perpendiculars in the triangle ABC. If H_1, H_2, H_3 be the ortho-centers of the triangles AYZ, ZBX, XYC, then the lines H_1X, H_2Y, H_3Z are concurrent.

83. If H_1', H_2', H_3' be the ortho-centers of the triangles HYZ, XCZ, XYB.

H_1'', H_2'', H_3'' be the ortho-centers of the triangles CYZ, XHZ, XYA.

H_1''', H_2''', H_3''' be the ortho-centers of the trianglas BYZ, XAZ, XYH.

And if T_1 be the homothetic center of the triangles XYZ and $H_1'H_2'H_3'$.

T_2 be the homothetic center of the triangles XYZ and $H_1''H_2''H_3''$.

T_3 be the homothetic center of the triangles XYZ and $H_1'''H_2'''H_3'''$.

Then AT_1, BT_2, CT_3 concur at the centroid of the triangle XYZ.

(Nos. 80, 81, 82, 83 are extracted from the work of Dr. Mackay in the Proceedings of the Edinburgh Math. Soc.)

84. If through K parallels be drawn to BC, CA, AB, they intersect the corresponding altitudes in A_1, B_1, C_1, respectively, which are the vertices of Brocard's first triangle. BA_1, CB_1, AC_1 concur at Ω; BC_1, CA_1, AB_1 concur at Ω', and thus the two Brocard points are determined.

Note on "Note on Smith's Definition of Multiplication." By A. L. Baker.

The rule should be: To multiply one quantity by another, perform upon the multiplicand the series of operations which was performed upon unity to produce the multiplier.

This does not mean, perform upon the multiplicand the series of successive operations which was performed upon unity and upon the successive results.

Thus, to multiply b by $\sqrt{a}$: If we attempt to consider $\sqrt{a}$ as derived by taking unity a times and then extracting the square root of the result, we violate the rule. To get $\sqrt{a}$ by performing operations upon unity, we must (e. g., a=2) take unity 1 time, .4 times, .01 times, .004 times, etc., and add the results. Doing this to b, we get the correct result, viz., $\sqrt{2}\ b = 1.414\ldots b$.

The rule is thus universal, applying to all multipliers, complex, quaternion and irrational.

The Geometry of Simson's Line. By C. E. Smith, Indiana University.

1. If from any point in the circumference of the circumcircle to a $\triangle$ ABC $\perp$s to the sides of the $\triangle$ be drawn, their feet, P_1, P_2, and P_3, lie in a straight line. This is known as Simson's Line.

(a) First proof that P_1, P_2, and P_3 lie in a straight line.

Since $\angle$s PP_3B and PP_1B (Fig. 1.) are both right $\angle$s, P, P_3, P_1 and B are concyclic.

Likewise P, P_2, A, and P_3 are concyclic.

Now $\angle PP_3P_1 + \angle PBP_1 = 180°$.

and $\angle PAC + \angle PBP_1 = 180°$.

$\therefore \angle PP_3P_1 = \angle PAC$,

But $\angle PAC + \angle PAP_2 = 180°$.

$\therefore \angle PP_3P_1 + \angle PAP_2 = 180°$.

But $\angle PAP_2 = \angle PP_3P_2$ (measured by same arc of auxiliary circle)

$\therefore \angle PP_3P_1 + \angle PP_3P_2 = 180°$, or a straight $\angle$.

$\therefore$ P_1 P_3 and P_2 lie in a straight line.

(b) Second proof that P_1, P_2, and P_3 lie in a straight line.

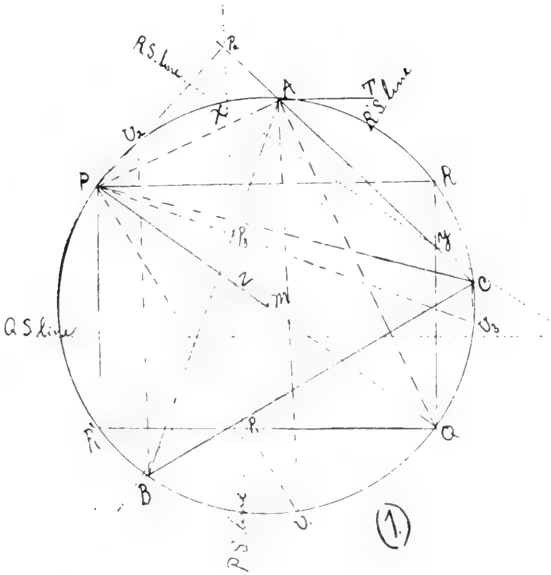
Draw PC and PA (Fig. 1).

Now $\angle$s PP_2C and PP_1C are right $\angle$s.

$\therefore$ P, P_1, C and P_2 are concyclic with PC as diameter.

$\angle PAB = \angle PCB = \angle PCP_1$,

and $\angle PP_2P_1 = \angle PCP_1$,



$\therefore \angle PAB = \angle PAP_3 = PP_2P_1$

Now P, P_2, A, P_3 are concyclic.

$\therefore \angle PP_2P_3 = PAP$ and

$\therefore \angle PP_2P_3 = \angle PP_2P_1$

$\therefore P_2P_1$ passes through P_3 and the three points are collinear.

2. If PP_1 be produced until it intersects the circumcircle of $\triangle$ ABC, at the point U_1, then AU_1 is $\parallel$ to Simson's line of P. (Fig. 1.)

Now the points P, P_1, P_2, and C are concyclic.

$\therefore$ the $\angle P_1PC = \angle P_1P_2C$.

But $\angle P_1PC = \angle U_1AC$, (arc CU_1 common to both)

and $\angle P_1P_2C = U_1AC$.

If two angles are equal and have a pair of sides in coincidence, then the other sides must also either coincide or be parallel. Hence AU || $P_1 P_2 P_3$, or to Simson's line. Thus we can show BU_2 and CU_3 parallel to Simson's line of P and therefore AU_1, BU_2 and CU_3 are parallel to each other.

3. Let AT (Fig. 1) be isogonal conjugate to AP. Then Simson's line of P ⊥ AT.

Also Simson's line of T ⊥ AP.

Now, AU_1 is || Simson's line of P, and

$\angle BAT = \angle PAC = 180° - \angle PU_1C$.

Also $\angle BAU_1 = \angle BCU_1$.

$\therefore \angle BAT - \angle PAU_1 = 180° - \angle PU_1C - \angle BCU_1$.

$\therefore U_1AT = 180° - 90° = 90°$. for $\angle PU_1C$ is measured by $\frac{1}{2}$ arc PC and $\angle BCU_1$ is measured by $\frac{1}{2}$ arc BU_1.

But PP_1C, which is a right ∠, is measured by $\frac{1}{2}$ arc $(PC + BU_1)$.

$\therefore U_1A \perp AT$ and so Simson's line of P must be. In like manner we can prove Simson's line of T ⊥ AP.

Now, if Q is the point on the circumference opposite P, then AU_1 and AQ are isogonal conjugate lines, for

$\angle U_1AT = \angle QAP = 90°$ and

$\angle TAC = \angle BAP$ with $\angle U_1AQ$ common.

$\therefore \angle U_1AT - \angle QAU_1 - \angle TAC = \angle QAP - \angle U_1AQ - \angle BAP$.

$\therefore \angle BAU_1 = \angle CAQ$.

4. If P and Q are opposite points on the circumference, their Simson's lines are ⊥ to each other.

Now, the isogonal conjugate of AP is ⊥ to isogonal conjugate of AQ, and, therefore, since the Simson's line of P || AU_1 and the Simson's line of Q AT, the Simson's line of P will be ⊥ to Simson's line of Q.

5. A side, BC, and its altitude in a triangle are the Simson's lines of A′ and A, respectively, where A′ is the point on the circumference opposite A. (Fig 4.)

Since the feet of the ⊥ s from A to AB and AC coincide with A, and the foot of the ⊥ from A to BC is H_a, therefore the Simson's line of A is AH_a. Again, the feet of ⊥ s from A′ to the sides AB, AC, and BC are B, C, and A'_a, respectively; hence BC is the Simson's line of A′.

Since AH_a, BH_b and CH_c are the Simson's lines of A, B, and C, respectively, their Simson's lines concur in H, the ortho-center.

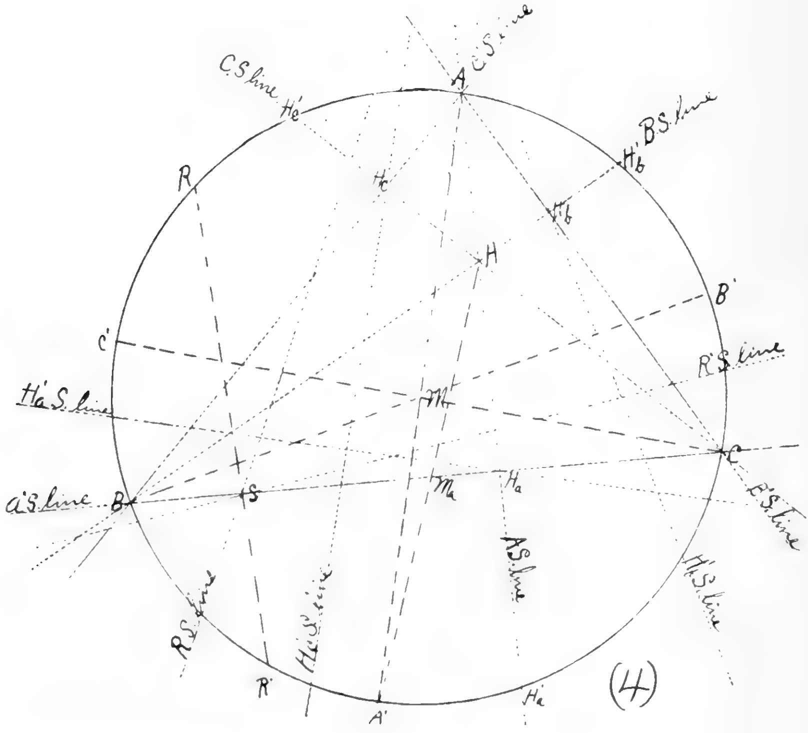
6. Let A′, B′ and C′ be the points on the circumference opposite A, B and C, respectively, and H_a', H_b', and H_c' be the points where AH_a, BH_a and CH_a, produced, cut the circumference, then the

Simson's lines of A, B′ and C′ concur in A,

Simson's lines of B, C′ and A′ concur in B, and

Simson's lines of C, A′ and B′ concur in C,

Also, since the Simson's line of H_a', H_b' and H_c' must pass through H_a, H_b and H_c, respectively, we have the



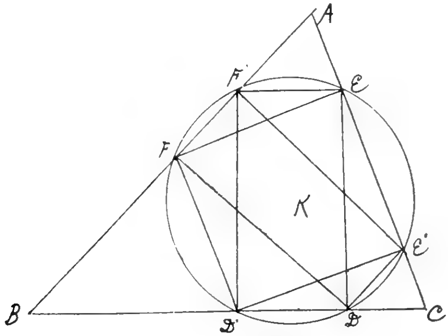
Simson's lines of A, A′ and H_a' concurring in H_a,

Simson's lines of B, B′ and H_b concurring in H_b and

Simson's lines of C, C′ and H_c' concurring in H_c.

Since the point of concurrency of the Simson's lines of the extremities of a chord ⊥ to BC is the point where this chord intersects BC, it follows that the Simson's lines of the extremities of all chords ⊥ to BC are concurrent with Simson's line of A′; the Simson's lines of extremities of all chords ⊥ AC are concurrent with Simson's line of B′; and the Simson's lines of the extremities of all chords $\perp$ AB are concurrent with Simson's line of C′. Thus there is a triple infinity of sets of three points on the circumcircle, the points of concurrency of the Simson's lines of which lie in the sides of the fundamental triangle.

7. Since, in the cosine circle (Fig. 6), F′ EDD′, FEE′ D′, and FF′ E′ D are all rectangular, it follows at once that the Simson's line of D′, with regard to rt. △ DEF, is FD, of E′, DE and of F′, EF. Also Simson's line of D, with regard to rt. △ D′E′F′, is D′ E′, of E, E′ F′ and of F, F′D′.



(6)

8. In Fig. 2, M_a, M_b, M_c are the midpoints of the sides of fundamental triangle opposite A, B, and C, respectively. H_a'', H_b'', H_c'' are the midpoints of AH, BH and CH, respectively, where H is the ortho-center.

Now $M_bA = M_bH_a$.

$\therefore \angle M_bH_aA = \angle M_bAH_a$.

Likewise $\angle M_cH_aA = \angle M_cAH_a$.

$\therefore \angle M_cH_aM_b = \angle A$.

We also know $\angle M_cM_aM_b = \angle A$.

$\therefore$ M_c, M_b, M_a and H_a are concyclic.

In the same way we can show

M_c, M_b, M_a and H_b and M_c, M_b, M_a, and H_c to be concyclic.

$\therefore$ Since three points determine a circle, these six points are all concyclic.

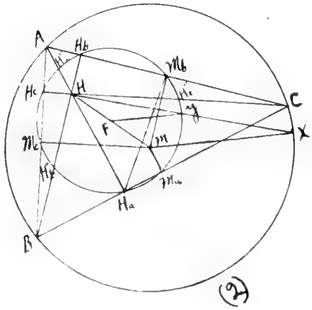
Now H_a, H_b, H_c are the feet of the altitudes of △ AHB.

But we have just shown that, in any triangle, the feet of its altitudes and the midpoints of its sides are all concyclic.

$\therefore$ H_a, H_b and H_c and H_a'', H_b'', and H_c'' are concyclic.

Then, since three points determine a circle, M_a, M_b, M_c, H_a, H_b, H_c, H_a'', H_b'' and H_c'' must all lie on the same circle. This circle, since it passes through nine definite points, is called the *nine-point* circle.

A $\perp$ to the midpoint of $H_a M_a$ meets HM at its midpoint, say F. So $\perp$s to $H_b M_b$ and $H_c M_c$ at their midpoints meet HM in F.



∴ F, the midpoint of HM, is the centre of the nine-point circle.

Since it is the circumcircle of rt. $M_a M_b M_c$, which has just half the dimensions of △ ABC, its radius will be just half the radius of the larger circle.

9. The nine-point circle bisects any line drawn from H to the circumcircle of the fundamental triangle.

Let MX and FY be any two radii of the two circles. Now, since F is the mid-point of MH and FY $= \frac{1}{2}$ MX, HYX is a straight line with Y as its mid-point.

10. Simson's line of P bisects PH. (Fig. 7.)

Let us suppose that D is the midpoint of PH. Then D lies on the nine-point circle. Then we must prove it lies on $P_1 P_2$.

Since $P P_1$ and AH are $\perp$ to BC, they are $\parallel$. Also since D is midpoint of PH, $\angle$ P, DH_a is isosceles. Let E be midpoint of AH. Then DE $= \frac{1}{2}$ AP.

D, E, and H_a are on the nine-point circle.

A, P, and C are on the circumcircle.

Then since DE $= \frac{1}{2}$ AP and radius of nine-point circle $= \frac{1}{2}$ R, $\angle$ EH_a D, inscribed in nine-point circle, $=$ $\angle$ ACP, inscribed in circumcircle.

$\angle$ EH_a D $=$ $\angle$ ACP $=$ $\angle$ DP_1 P.

Let the intersection of P_1 D and AC be P_2,

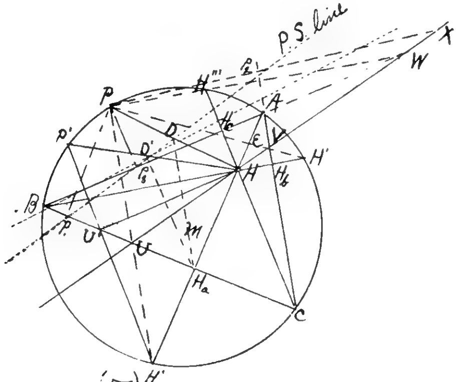
Then $\angle$ PP_1 D $=$ $\angle$ ACP $=$ $\angle$ PCP_2,

$\therefore$ P, P_1, C, and P_2 are concyclic and $\therefore$ $\angle PP_2C = \angle PP_1C = 90°$ and $PP_2 \perp AC$.

$\therefore$ P_1 D is Simson's line of P.

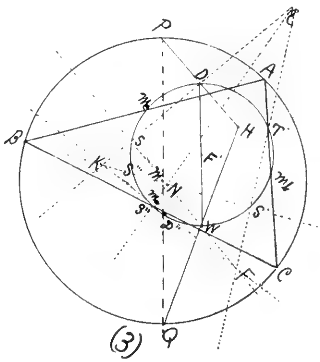
The point where PH cuts Simson's line of P is called its *center.*

11. The line joining A′, the point opposite the vertex A of $\triangle$ ABC (Fig. 4), with H, the ortho-centre, bisects the side BC.



(7)

For, the Simson line of A′ is BC, $\therefore$ BC bisects A′ H, and, as we have shown, this bisection is on the nine-point circle. But the nine-point circle cuts BC at two places only, at H_a and M_a; hence it is obvious that A′ H passes through M_a, and thus it bisects BC.



(3)

12. S, the intersection of the Simson lines of P and Q, the extremities of any diameter of the circumcircle, lies on the nine-point circle. (Fig. 3.)

Take W as the midpoint of QH and D of PH. Then they are both on the nine-point circle and WD must be its diameter, since it is ∥ and equal to $\frac{1}{2}$ QP. Then, as ∠ S is a right ∠, S must also lie on the nine-point circle. S is called the *vertex* of either Simson line.

13. H′, H″ and H‴ (Fig. 7) are the points on the circumcircle through which AH, BH and CH, respectively, pass.

U is the point where PH′ cuts BC.

V is the point where PH″ cuts AC.

W is the point where PH‴ cuts AB.

Now, U, V, H and W lie on a straight line ∥ to the Simson line of P.

$\angle VHH_b = \angle VH''H_b$, ($H_b$ is midpoint of HH″.)

$= \angle PH''B = \angle PCB.$

$\angle UHH_a = UH'H_a = \angle PH'A = \angle PCA.$

Also H, H_a, C, and H_b are concyclic.

$\therefore \angle H_aHH_b + \angle C = 180°.$

But we have just proven $\angle VHH_b + \angle UHH_a = \angle C.$

$\therefore \angle H_aHH_b + \angle VHH_b + UHH_a = 180°$, and

∴ U, H and V are collinear.

Now, $\angle WHH''' = WH'''H = 180° - \angle PH'''C.$

$= \angle B + \angle UH'H.$

$= \angle B + \angle UHH'.$

Also B, H_a, H, and H_c are concyclic.

$\therefore \angle B + \angle H_aHH_c = 180°$ and

$\therefore \angle B + \angle UHH' + \angle H_cHU = 180°.$

So then $\angle WHH''' + \angle H_cHU = 180°$, which proves W, H and U collinear.

Therefore all four points, W, V, H and U must be collinear.

Now, PP_2 is ∥ to HH″, for both are ⊥ to AC.

∴ △ PVX is isosceles, and $PP_2 = P_2X$.

Now, $\angle P_2XV = \angle PCP_1$ and P, P_2, C, and P_1 are concyclic.

$\therefore \angle PP_2P_1 = \angle PCP_1 = \angle P_2XV.$

∴ $P_1P_2P_3$ is ∥ to UVW.

From this we can also see that Simson's line of P bisects all lines from P to the line WVHU.

14. The angle between the Simson lines of two points P and P′ is equal to an ∠ inscribed in the circumcircle with PP′ an arc and also to an angle inscribed in the nine-point circle with arc equal to the part of the circumference included between the centers of their Simson's lines.

Draw $P'H'$ (Fig. 7), letting it cut BC in U'. Then, from above proposition, $HU' \parallel$ to Simson's line of P'. Also $HU \parallel$ to Simson's line of P.

$\therefore \angle (S, S') = \angle (HU, HU')$. Now, H is the center of similitude of the circumcircle and the nine-point circle. Draw $P'H$, letting it cut the Simson line of P' at D'.

Then P and D, P' and D' and H' and H_a are corresponding points.

$\therefore H_aD$ and H_aD' and $H'P$ and $H'P'$ are $\parallel$ lines, whence $\angle DH_aD' = \angle PH'P' = \angle U'HU$.

15. If P and Q (Fig. 1) be the extremities of a diameter and R and R' two other opposite points such that PR and QR' are $\perp$ to Simson's line of P and PR' and QR are $\perp$ to Simson's line of R, then the Simson's line of R is parallel to PQ and Simson's line of R' is $\perp$ to PQ.

Since the angle between the Simson's lines of two points is equal to an angle inscribed in the arc between them, we know that $\angle ZXY = \angle YQZ$. Also $ZX \parallel QY$.

$\therefore$ QZXY is a parallelogram, and XY, the Simson's line of R, is $\parallel$ to PQ. Then it follows that Simson's line of R is $\perp$ to PQ, since it is conjugate to Simson's line of R.

16. If ES and FS (Fig. 3) are the Simson's lines of opposite points on the circumcircle, and EF be any other Simson's line, then $T'E = T'F = T'S$, where T' is the center of the last named Simson's line.

$\angle T'ED = \angle T'SD$ (a previous proposition).

$\therefore T'E = T'S$. In like manner we can show $T'F = T'S$. $\therefore T'E = T'F$.

The Simson's lines of opposite points on the circumcircle are said to be *conjugate.*

17. The arc between the vertices of two Simson's lines (not conjugate) is twice as large as the arc between their centers. For $ET'S$ is an isosceles $\triangle$ and $\angle ET'S = 2\ T'ST$. But $ET'S = S'T'S$. $\therefore$ arc $SS' = 2$ arc $T'T$. Now suppose $T'S$ is less than R (it never can be greater), then S'' could be another point on the nine-point circle such that $T'S'' = T'S$ and $\angle ES''F$ would also be a right $\angle$. It is thus evident that there are always two pairs of conjugate Simson's lines passing through E and F.

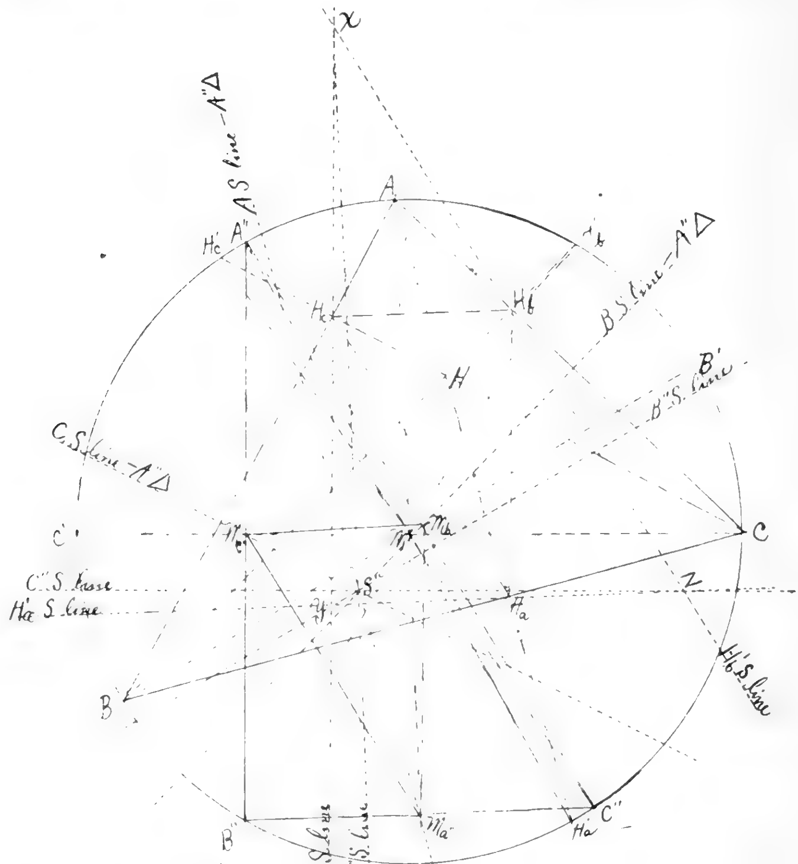
The limit of EF is 2R.

For when S and S'' coincide at S''', $T'S''' = T'E = T'F = r$. In this case we have but one pair of conjugate Simson's lines.

18. If two Simson's lines, SD and $S''D''$, which are not conjugate, cut a third Simson's line, $T'S'$, at equal distances, E and F, from its center, T', then

the line joining the point of intersection, K, of SD and S″D″ with S′, the vertex of T′S′ is a Simson's line conjugate to T′S′.

Let ES and FS″ intersect at K, and ES″ and FS intersect at N (Fig. 3). Since the pair of lines, ES, FS and ES″, FS″ are conjugate Simson's lines, they



(5)

are ⊥ to each other, or ES″ and FS are altitudes in the △ EKF. Therefore KN is the third altitude, and we may prove S′ to be the foot of this altitude on EF.

The nine-point circle of the △ ABC passing through the feet, S and S″, of the two altitudes, and through the middle point, T′, of one side of the △ EKF, must be also the nine-point circle of the △ EKF, and therefore the second intersection of the nine-point circle with the side, EF, must be the foot of the altitude to EF, or KS′.

Hence S′ is the foot of the altitude KN. But any side and its altitude is a pair of conjugate Simson's lines, and since EF is a Simson's line of a point on the circumcircle of ABC, KN is the Simson's line conjugate to EF.

Any triangle like EKF formed by three Simson's lines, the altitudes of which are Simson's lines conjugate to the sides, and having the nine-point circle in common with the triangle ABC, we shall call a *Simson Triangle.*

Since the nine-point circle is common to both triangles ABC and EKF, the radius of the nine-point circle is one-half the radius of the circumcircle of either triangle; therefore the radius of the circumcircle of any Simson triangle is equal to the radius of the circumcircle of the original triangle.

19. The common vertex S‴ of the pair of limiting Simson's lines belonging to TS is on the same straight line as K, N and S′. For, since T′S‴ is a diameter of the nine-point circle, $\angle$ T′S′S‴ $= 90°$, or S′S‴ $\perp$ to EF. $\therefore$ S‴ is on the altitude KS′.

20. A″, B″ and C″ are points on the circumference opposite H_a', H_b' and H_c' respectively. (Fig. 5.) Prove that the Simson's lines of A″, B″, and C″ are $\parallel$ respectively to AA′, BB″ and CC″ and that they are $\perp$ respectively to B″C″, A″C″, A″B″. Now the angle between the Simson's lines of A and A″ will be equal to an angle measured by $\frac{1}{2}$ arc AA″. But the angle between AA′ and AH_a, the Simson's line of A, is measured by an arc equal to this. Therefore Simson's line of A″ is $\parallel$ to AA′. So the Simson's line of B″ is $\parallel$ to BB′ and Simson's line of C″ $\parallel$ to CC′.

Now arc H_b' CB″ = arc H_c' BC″ $= 180°$.

$\therefore$ arc H_b' CC″ = arc H_c' BB″

$\therefore$ H_b' H_c' $\parallel$ B″ C″, also H_b' H_a' $\parallel$ A″ B″ and

H_a' H_c' $\parallel$ A″C″. Therefore $\triangle$ A″ B″ C″ is equivalent to $\triangle$ H_a' H_b' H_c', being inscribed in same circle and having sides equal and parallel.

$\angle$ H_c'CA = $\angle$ H_b' BA. (From similarity of $\triangle$s ABH_b and ACH_c).

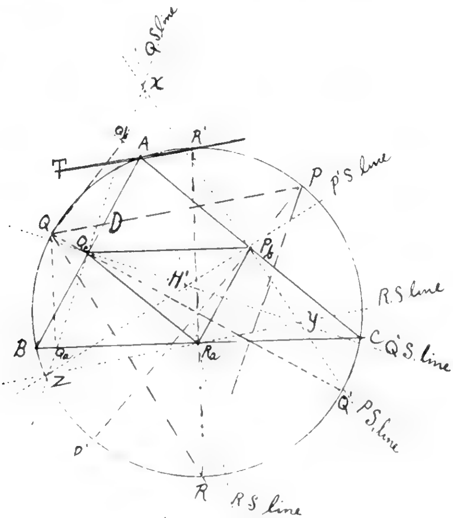
$\therefore$ arc AH_b' = arc AH_c', $\therefore$ since AA′ is a diameter it must be $\perp$ to chord H_c' H_b' and therefore to B″ C″. So we may prove BB′ $\perp$ A″ C″ and CC′ $\perp$ A″ B″.

21. The Simson's lines of H_a' H_b' H_c' form a Simson's triangle XYZ of which the Simson's lines of A″, B″, C″ are the altitudes, A″, C″, B″ being points opposite H_a', H_b', H_c' respectively.

Let Simson's lines of H_b', H_c', and H_c', H_a' and H_a', H_b' concur in X, Y, and Z respectively.

The Simson's lines of A'' and H_a', of B'' and H_b', and of C'' and H_c' are conjugate, therefore their intersections, u, v, and w will lie on the nine-point circle of rt △ ABC. The Simson's lines of H_a', H_b' and H_c' must pass through H_a, H_b, H_c respectively and therefore rt △ XYZ must have the same nine-point circle as △ ABC. Now since H_a, H_b and H_c can not be the feet of altitudes they must be the midpoints of the sides and therefore u, v and w must be the feet of altitudes.

Thus the four points of concurrency are established, namely X, Y, Z and S''. S'', being formed by the intersection of the altitudes of △ XYZ, is the orthocenter of the same.



(8)

22. If R, P and Q (Fig. 8) be taken as the midpoints of arcs BC, AC and AB, respectively, and R', P' and Q' be the points on the circumference opposite R, P, and Q, then the Simson's lines of R, P, and Q will form a △ XYZ, the altitudes of which will be the Simson's lines of R', Q' and P'.

It may be assumed that XYZ is the triangle formed by the intersection of the Simson lines of R, P and Q. That the Simson's line of Q' is the altitude on side XZ may be established thus:

$\angle AQ_bQ_c = \angle A - \angle AQ_cQ_b.$

But, since Q, Q_c, A, and Q_b are concyclic, $\angle AQ_bQ_c = \angle AQQ_c$, which is measured by $\frac{1}{2}$ arc AQ'.

Also, since Q, B, Q_a, and Q_c are concyclic, $\angle BQQ_c = 180° - \angle BQ_aQ_c$.

$\therefore \angle Q_cQ_aC = \angle BQQ_c$, which is measured by $\frac{1}{2}$ arc BQ'. But arc $BQ'=$ arc AQ'.

(A.) $\therefore \angle AQ_bQ_c = \angle CQ_aQ_c$.

But $\angle AQ_bQ_c = \angle A - \angle AQ_cQ_b$, and

$\angle CQ_aQ_c = \angle B + \angle BQ_cQ_a$.

$= \angle B + \angle AQ_cQ_b$.

Now the Simson's line of Q' is $\perp$ to Q_bQ_a the Simson's line of Q, at Q_c, and $\angle AQ_cP_b = \angle B$ and $\angle BQ_cR_a = \angle A$. And from (A.) we know that $\angle Q_bQ_cP_b = \angle Q_aQ_cR_a$, $\therefore \angle P_bQ_cH', = \angle R_aQ_cH'$ and thus Simson's line of Q' is proven to be the internal bisector of $\angle Q_c$ in rt. $\triangle R_aP_bQ_c$. In like manner the Simson's line of R' may be proven to be the internal bisector of $\angle R_a$, and Simson's line of P', the internal bisector of $\angle P_a$ of same triangle. Since the Simson's lines of Q, R, and P are $\perp$ to these internal bisectors at the vertices of the $\triangle$, they must be the external bisectors of the same angles. But we know that the internal and external bisectors of the $\angle$s of a triangle concur in four points. Thus X, Y, Z and H' are each points of concurrency of three Simson's lines. H', of course, is the ortho-center of $\triangle XYZ$.

23. $\triangle XYZ$ has the same nine-point circle as $\triangle ABC$ and is therefore inscribable in the same sized circle as rt. $\triangle ABC$.

That it has the same nine-point circle follows easily from the fact that three points that must lie on its nine-point circle, the feet of its altitudes, are coincident with three points on the ABC nine-point circle, the midpoint of its sides. Since three points determine a circle, their nine-point circles must be identical.

24. The Simson's line of P is $\parallel$ to RQ, Simson's line of R is $\parallel$ to PQ, and Simson's line of Q is $\parallel$ to RP.

The Simson's line of R will be $\perp$ to Simson's line of R', so let us prove Simson's line of R' $\perp$ to PQ'.

Now, the Simson's line of R' will be $\perp$ to the line isogonal conjugate to AR' which we call AT. Then let us prove $AT \parallel$ to PQ.

To be $\parallel$ $\angle ADP$ must $= \angle CAR'$.

$\angle ADP$ is measured by $\frac{1}{2}$ arc $(AP + BQ)$.

$\angle CAR'$ is measured by $\frac{1}{2}$ arc CR'.

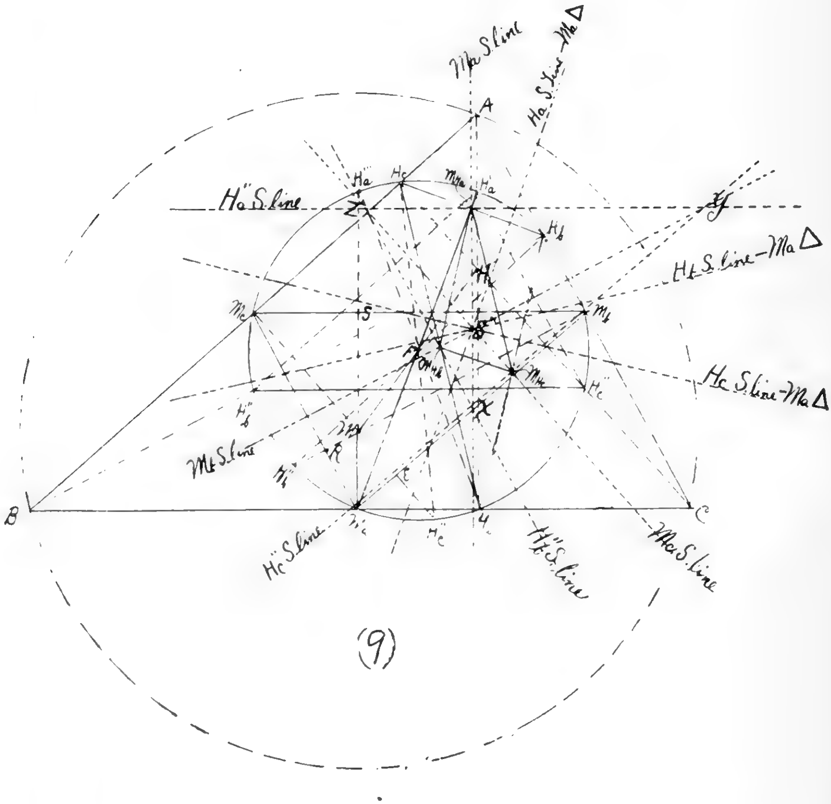
Arc $AP =$ arc CP, and $\frac{1}{2}$ arc BQ measures $\frac{1}{2} \angle C$.

Now, $\angle$ PRR′ $= 90° -$ PR′R.

$= 90° - \frac{1}{2}$ (A + B).

$= \frac{1}{2}$ C.

$\therefore$ arc BQ $=$ arc PR′, and so $\angle$ ADP $= \angle$ CAR′. Hence AT is ‖ PQ and $\therefore$ Simson's line of R is ‖ to PQ. In like manner we may prove Simson's line of P ‖ to RQ, and Simson's line of Q ‖ to RP.



(9)

25. The Simson's lines of H_a'', H_b'', H_c'' (Fig. 9) with respect to $\triangle$ $H_aH_bH_c$, inscribed in the nine-point circle, form a rt. $\triangle$ XYZ, the altitudes of which are the Simson's lines of M_a, M_b and M_c with respect to the same rt. $\triangle$.

H, the orthocenter of $\triangle$ ABC, is the incenter of $\triangle$ $H_aH_bH_c$, for $\angle$s AH_cH and AH_bH being right $\angle$s, A, H_c, H and H_b are concyclic with AH as diameter.

H_a'', being midpoint of AH, is the center and therefore chord $H_a''H_b$ = chord $H_a''H_c$. Therefore H_aH_a'' bisects ∠ H_a, H_bH_b'' bisects ∠ H_b, and H_cH_c'' bisects ∠ H_c.

H_a'', H_b'' and H_c'' are points on the nine-point circle opposite M_a, M_b, M_c, respectively, for, since MM_a and H_aH_a'' are and the center of the nine-point circle is F, the midpoint of MH, a line from M_a through F, will meet AH_a on the circumference of the nine-point circle, necessarily at H_a''. In like manner H_b'' can be shown to be opposite M_b, and H'' opposite M_c.

This proves $H_a''H_b''$ ∥ to M_aM_b and equal to it, and therefore ∥ to AB, $H_b'H_c'$ equal to M_bM_c and parallel to both M_bM_c and BC, and $H_c''H_a''$ equal to M_cM_a and parallel to both M_cM_a and CA.

Now, the Simson's line of M_a will be ⊥ to BC and to AH_a, for H_aC is isogonal conjugate to H_aM_a since AH_a bisects ∠ $H_bH_aH_c$, thus making ∠ CH_aH_b = ∠ $M_aH_aH_c$. Therefore the Simson's line of H_a'', since it is conjugate to Simson's line of M_a, is ∥ to M_cM_b, $H_b''H_c$ and BC. In like manner we can prove the Simson's line of M_b ⊥ AC and to BH_b and, therefore, the Simson's line of H_b'' to M_aM_c, $H_c''H_a''$ and AC; and Simson's line of M_c ⊥ AB and to CH_c and, therefore, the Simson's line of H_c'' ∥ to M_aM_b, $H_b''H_a''$ and AB.

Now △ $M_{Ha}M_{Hb}M_{Hc}$ is oppositely similar to △ $H_aH_bH_c$. Also, from what we have proven before, the Simson's lines of M_a and H_a'' must both pass through M_{Ha}. Then the Simson's line of M_a being ∥ to AH_a, will bisect ∠ $M_{Hb}M_{Ha}M_{Hc}$. In like manner we can show that the Simson's lines of M_b and M_c bisect ∠s M_{Ha} $M_{Hb}M_{Hc}$ and $M_{Ha}M_{Hc}M_{Hb}$. Now the Simson's lines of H_a'', H_b'' and H_c'' are ⊥ to Simson's lines of M_a, M_b and M_c, respectively, and therefore they are the external bisectors of the ∠s of the rt. △ $M_{Ha}M_{Hb}M_{Hc}$. Since the internal and external bisectors of a △ meet by threes in four points, we may conclude the Simson's lines of M_a, H_b'', and H_c'' concur in X, Simson's lines of M_b, H_c'', and H_a'' concur in Y, Simson's lines of M_c, H_a'', and H_b'' concur in Z, and Simson's lines of M_a M_b M_c concur in S'''. S''', we see, is the orthocenter of △ XYZ and in-center of △ $M_{Ha}M_{Hb}M_{Hc}$.

△ XYZ has its sides ∥ to sides of △ $M_aM_bM_c$ and oppositely ∥ to △s $H_a''H_b''$ H_c'' and ABC.

26. Let us prove △ XYZ equivalent to △s $M_aM_bM_c$ and $H_a''H_b''H_c''$ and, therefore, inscribable in the nine-point circle.

△ $M_{Ha}M_{Hb}M_{Hc}$ bears the same relation to △ XYZ that △ $H_aH_bH_c$ does to △ ABC. Therefore, since △ $M_{Ha}M_{Hb}M_{Hc}$ is ¼ the size of △ $H_aH_bH_c$, △ XYZ must be ¼ the size of rt. △ ABC and thus equivalent to △ $M_aM_bM_c$, and rt. △ H_a'' $H_b''H_c''$ and hence inscribable in the nine-point circle of the fundamental △.

27. If $H_a''' H_b''' H_c'''$ are the points on the nine-point circle opposite H_a H_b and H_c respectively, then the Simson's lines of M_c, H_c'', and H_c''' concur in M_{Hc}, for H_a H_b is Simson's line of H_c'''. Likewise the Simson's lines of M_b, H_b'' and H_b''' concur in M_{Hb} and the Simson's lines of M_a, H_a'', and H_a''' concur in M_{Ha}.

28. Now considering M_a M_b M_c as the reference △ in the nine-point circle, let us prove that the Simson's lines of these same points, *i. e.*, M_c, H_c'' and H_c''', etc., concur.

Chord M_c H_c''' is ∥ H_c H_c'' and ∴ ⊥ to M_a M_b. This is true because ∠ H_c M_c H_c''' is a right ∠.

The Simson's line of M_c will be this chord M_c H_c''', the Simson's line of H_c''' will pass through E, the foot of this altitude, and the Simson's line of H_c'' will be side M_a M_b since it is a point opposite the vertex M_c.

So, also, the Simson's lines of M_b, H_b'' and H_b''' will concur in R, and the Simson's lines of M_a, H_a'', and H_a''' concur in S.

29. Now by noticing the lettering and arrangement of (Fig. 17) it will be seen that H_a''', H_b''' and H_c''' correspond to H_a', H_b' and H_c' of that figure, and that H_a, H_b, and H_c correspond to A″, B″, and C″ of that figure. Therefore we know at once that the Simson's lines of H_a, H_b and H_c and of H_a''', H_b''' and H_c''' concur just as in that case by threes in four different points, the point of concurrency of H_aH_b and H_c being the ortho-center S‴ of the triangle formed by the intersection of the Simson's lines of the other three points.

30. Also since $H_a''H_b''H_c''$ and points H_a, H_b and H_c bear the same relation to the nine point circle that △ ABC as points H_a', H_b', and H_c' do to the circle in Fig. 5, it follows at once that what was true of the Simson's lines of those points is also true of these.

Depending upon this same comparison between Figs. 5 and 9 it follows that the Simson's lines of points A, B and C in Fig. 5 concur at in-center of rt. △ $M_{a''}M_{b''}M_{c''}$.

31. Now let us prove that S″ (Fig. 5), the point of concurrency of Simson's lines of A″, B″, C″, is also the in-center of △ $M_{a'}M_{b''}M_{c''}$.

We have already proven that the Simson's lines of H_a', H_b' and H_c' form a Simson triangle XYZ, of which the Simson's lines of A″, B″ and C″ are the altitudes, and that △ XYZ, is equivalent to △ A″B″C″ with their sides respectively ∥. Now, since H_a, H_b and H_c are the midpoints of the sides of △ XYZ, △ $H_aH_bH_c$ will be equal in every respect and similarly placed to △ $M_{a''}M_{b''}M_{c''}$. We have also proven H to be the in-center of this △ $H_aH_bH_c$. Again, since the Simson's lines of A″, B″ and C″ bisect A″ H, B″ H and C″ H, respectively, it is clear that if △ XYZ were to be given the rank of rt. ∠ A″B″C″ and a new one were to be formed from it, as it is formed from ∠ A″B″C″, then the point S″ would fall upon H. Therefore, since H is the in-center of △ $H_aH_bH_c$, S″ must be the in-center of △ $M_{a''}M_{b''}M_{c''}$.

Therefore we see that the six Simson's lines, three with reference to one △ and three with reference to the other, meet in the same point.

32. This, at the same time, establishes another even more interesting proposition, namely: If the Simson's lines of the vertices of a first △ with reference to a second △ concur in a point S″, then the Simson's lines of the vertices of the second △ with reference to the first △ concur in the same point S″.

The broad scope covered by this proposition would enable me to double in number the points of concurrency of Simson's lines, but there would be little benefit in merely pointing them out, as the interested reader can easily see them for himself.

A Bibliography of Foundations of Geometry. By Morton Clark Bradley.

Euclid's treatment of parallels and angles and his definitions and axioms—particularly his twelfth—are the points of controversy that cause the most discussion. For nearly twenty centuries Euclid's work remained unquestioned. Since John Kepler's day, however, there have been new theories constantly advanced, theories built on axioms and definitions, a part of which, at least, are different from those of Euclid. The most important of the non-Euclideans are John Bolyai, Lobatschevski, Helmholtz, Riemann, Clifford, Henrici, Caley, Sylvester and Ball. The most prominent exponent of the non-Euclidean ideas in this country is Prof. Geo. Bruce Halsted, of Texas University. These mathematicians hold that Euclid's twelfth axiom is not, strictly speaking, an axiom—that it is not "a self-evident and necessary truth," but that it requires demonstration. They claim, too, that his definitions are not sufficient nor necessarily intelligible. Some of these men have built up new theories upon their substituted axioms and definitions, retaining those of Euclid that fit their theories. A few of these "reform" works are mere quibbles on words, but others deserve the serious consideration of all interested in pure geometry.

The list following is a complete list of English references to be found in the mathematical library of the University of Indiana or in the private library of Dr. Aley. Chrystal says the bibliography credited to Mr. Halsted contains all the references up to its time, save one, giving the non-Euclidean arguments. The list is not complete in arguments for Euclid, it being impossible to enumerate all the editions of Euclid, edited and upheld by the different mathematicians. The list is complete enough, however, to assure the reader that there are arguments for Euclid as well as against him.

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Point-Invariants for the Lie Groups of the Plane.

By David A. Rothrock.

Among the many interesting and important applications of Lie's Theory of Transformation Groups none deserves more prominent mention than the application to invariant theory. Whether the invariants dealt with be functions or equations, surfaces and curves or points, equally interesting results are obtained. The present paper has to do with the determination of the point-invariants for the finite continuous groups of the plane as classified by Lie in Vol. XVI. of the Mathematische Annalen. In the first part of the paper is sketched a brief outline of the Lie theory leading up to the point-invariant, then follow the calculations of the invariant functions.

An infinitesimal point-transformation gives to x and y the increments

$$\delta x = \xi\,(x, y)\,\delta t,\ \delta y = \eta\,(x, y)\,\delta t,$$

respectively, where δt is an infinitesimal independent of x and y. Such infinitesimal transformations move a point x, y through a distance

$$\sqrt{\delta x^2 + \delta y^2} = \sqrt{\xi^2 + \eta^2} \cdot \delta t,$$

and in a direction given by

$$\delta y : \delta x = \eta : \xi.$$

The variation of any function φ (x, y) by this infinitesimal transformation is given by

$$\delta\varphi = \frac{d\varphi}{dx}\delta x + \frac{d\varphi}{dy}\delta y = \left\{ \xi (x, y) \frac{d\varphi}{dx} + \eta (x, y) \frac{d\varphi}{dy} \right\} \delta t.*$$

The variation of a function f (x, y) may be taken as a definition of an infinitesimal transformation; in the Lie notation we have an infinitesimal transformation defined by

$$Xf \equiv \xi (x, y) \frac{df}{dx} + \eta (x, y) \frac{df}{dy}.$$

If a function φ (x, y) is to remain invariant by the operation X f, then the variation

$$\delta \varphi (x, y) = X\varphi . \delta t$$

must vanish. Hence, a function φ (x, y) invariant by the infinitesimal transformation X f is determined as a solution of the linear partial differential equation

$$Xf \equiv \xi (x, y) \frac{df}{dx} + \eta (x, y) \frac{df}{dy} = 0.$$

The infinitesimal transformation X f may be *extended* to include the increments of the co-ordinates of any number of points x_i, y_i, (i = 1, 2 .... n). We shall write this extended transformation thus:

$$Wf \equiv \sum_1^n{}_i X^{(i)}f \equiv \sum_1^n{}_i \left(\xi (x_i, y_i) \frac{df}{dx_i} + \eta (x_i, y_i) \frac{df}{dy_i} \right) \quad . \ . \ . \ . \ (2)$$

The functions of the co-ordinates of n points invariant by Wf will be the 2 n — 1 independent solutions of Wf = 0. n of these solutions may be selected in the form φ (x_i, y_i), where φ (x, y) is a solution of X f = 0; the remaining n–1 solutions will in general differ from ϕ (x, y) in form.†

r infinitesimal transformations $X_1 f$, $X_2 f$ .... $X_r f$ are called *independent* when *no* relation of the form

$$c_1 X_1 f + c_2 X_2 f + \ldots\ldots + c_r X_r f = 0, \ (c_i = \text{const.}),$$

exists. If r independent infinitesimal transformations $X_k f$, (k = 1...r), be so related as to form a group, then will

$$X_i (X_k f) - X_k (X_i f) = \sum_1^r{}_s c_{iks} X_s f, \ (c_{iks} = \text{constants}) \quad . \ . \ . \ (3)$$

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* Throughout this paper $\frac{df}{dx}, \frac{df}{dy}$ are employed to denote *partial* differentials of f with respect to x and y.

† Lie: Theorie der Transformationsgruppen, Bd. I., § 59.

The transformations of the *r-parameter* group X_kf may be extended according to the method of (2) above, giving

$$W_kf = \sum_1^n iX_k^{(i)}f, \ (k=1 \ldots r),$$

which determine the increments of a function f $(x_1, y_1; x_2, y_2; \ldots x_n, y_n)$. Since the relations (3) exist for X_if, X_kf, they must also exist for W_if, W_kf, that is

$$W_i(W_kf) - W_k(W_if) = \sum_1^r s \ c_{iks} W_sf.$$

Hence, $W_1f=0$, $W_2f=0$, ... $W_rf=0$ are known to form a *complete* system of linear partial differential equations in $2n$ variables x_i, y_i, with at least $2n-r$ independent solutions. These $2n-r$ solutions are the invariants of the co-ordinates of n points by the r-parameter group X_kf. These solutions we shall call *point-invariants.*

According to the method here outlined we shall determine the *point-invariants* of the finite continuous groups of the plane. In Lie's classification these groups are divided into two classes: (1) Inprimitive, or those groups which leave invariant *one* or *more* families of ∞' curves; (2) Primitive, or those groups leaving invariant *no* family of ∞' curves. Subdivisions of the imprimitive groups will be indicated in the text.

NOTE.—The results of the present paper were worked out early in the spring of 1898. Since that time there has appeared a short article by Dr. Lovette, June number, 1898, of Annals of Mathematics, upon the same subject. Only a few of the *projective* groups are considered, however. Among these are the special linear, and general linear groups.

SECTION I. INVARIANTS OF SUCH IMPRIMITIVE GROUPS AS LEAVE UNCHANGED MORE THAN ONE FAMILY OF ∞' CURVES.

The groups of this category have been reduced by Lie to such canonical forms that they leave invariant:

(A) ∞^∞ of families of ∞' curves: $\phi(x)+\psi(y)=$constant,

(B) A single infinity of families of ∞' curves: $ax+by=$constant,

(C) Two families of ∞' curves: $x=$constant, $y=$constant.

(A) *The totality of curves* $\phi(x)+\psi(y)=$constant *remains invariant.*

1. $\boxed{q}$.*

* Lie employs this symbol to enclose the members of a continuous group;

$$p=\frac{df}{dx}, \quad q=\frac{df}{dy}.$$

This is the only group of the class (A), and furnishes us when *extended* the linear partial differential equation

$$Wf = \sum_1^n i \frac{df}{dy_i} = 0.$$

The invariants of the co-ordinates of n points by this group will be the $2n-1$ independent solutions of $Wf = 0$, *i. e.*

$$x_i,\ \psi_j = y_1 - y_j,\ (i = 1 \ldots. n,\ j = 2 \ldots. n).$$

B. *All families of curves of the form* $ax + by =$ constant *remain invariant.*

2. $\overline{| \quad p, q \quad |}$.

The complete system corresponding to this group is

$$W_1f = \sum_1^n i \frac{df}{dx_i} = 0,\quad W_2f = \sum_1^n i \frac{df}{dy_i} = 0,$$

with solutions

$$\phi_j = x_1 - x_j,\ \psi_j = y_1 - y_j,\ (j = 2 \ldots. n).$$

The functions ϕ, ψ are the required invariants.

3. $\overline{| \quad q, xp + yq \quad |}$.

From this group we have

$$W_1f = \sum_1^n i \frac{df}{dy_i} = 0,\ W_2f = \sum_1^n i \left\{ x_i \frac{df}{dx_i} + y_i \frac{df}{dy_i} \right\} = 0.$$

These two linear partial differential equations evidently have as solutions

$$\xi_j = \frac{x_j}{x_1},\ u_k = \frac{y_1 - y_k}{y_1 - y_2},\ \sigma = \frac{y_1 - y_2}{x_1},\ (j = 2 \ldots n,\ k = 3 \ldots n),$$

which are the invariants sought.

4. $\overline{| \quad p, q, xp + yx \quad |}$.

This three-parameter group furnishes us the complete system

$$\sum_1^n i \frac{df}{dx_i} = \sum_1^n i \frac{df}{dy_i} = \sum_1^n i \left\{ x_i \frac{df}{dx_i} + y_i \frac{df}{dy_i} \right\} = 0.$$

The first two of these equations have solutions

$$\phi_j = x_1 - x_j,\ \psi_j = y_1 - y_j,\ (j = 2 \ldots n),$$

which as new variables reduce the last equation to the form

$$\sum_2^n j \left\{ \phi_j \frac{df}{d\phi_j} + \psi_j \frac{df}{d\psi_j} \right\} = 0.$$

Hence, the invariants are

$$U_k = \frac{\phi_k}{\phi_2} = \frac{x_1 - x_k}{x_1 - x_2},\ V_k = \frac{\psi_k}{\psi_2} = \frac{y_1 - y_k}{y_1 - y_2},\ \sigma = \frac{y_1 - y_2}{x_1 - x_2},\ (k = 3 \ldots n).$$

(C.) *The families of curves* $x = constant$, $y = constant$, *remain invariant.*

5. $\left|\overline{q,\ yq}\right|$.

The complete system corresponding to this group,

$$\sum_1^n {}_i \frac{df}{dy_i} = \sum_1^n {}_i\, y_i \frac{df}{dy_i} = 0,$$

has as solutions

x_i, and $\psi_k = (y_1 - y_k) : (y_1 - y_2)$, $(i = 1 \ldots . n,\ k = 3 \ldots . n)$.

Hence, x_i and ψ_k are the invariants.

6. $\left|\overline{q,\ yq,\ y^2q}\right|$.

This is the general projective group in one variable, and leaves invariant x_i and the cross-ratios of any four ordinates.

$$\sum_1^n {}_i \frac{df}{dy_i} = \sum_1^n {}_i\, y_i \frac{df}{dy_i} = \sum_1^n {}_i\, y_i^2 \frac{df}{dy_i} = 0.$$

The first two equations of this system have solutions x_i, ψ_k of 5 above. Introducing these solutions as new variables in the last equation, we have

$$\sum_3^n {}_k\, \psi_k\, (\psi_k - 1) \frac{df}{d\psi_k} = 0,$$

whose solutions are

$$x_i,\ \xi_l = \frac{\psi_l - 1}{\psi_l} : \frac{\psi_3 - 1}{\psi_3} = \frac{y_2 - y_l}{y_2 - y_3} : \frac{y_1 - y_l}{y_1 - y_3},\ (l = 4 \ldots . n).$$

7. $\left|\overline{q,\ yq,\ p}\right|$.

This group leaves invariant

$\psi_k = (y_1 - y_k) : (y_1 - y_2)$, and $\phi_j = x_1 - x_j$, $(k = 3 \ldots . n,\ j = 2 \ldots . n)$.

8. $\left|\overline{q,\ yq,\ y^2q,\ p}\right|$.

The invariants of this group are clearly

$$\xi_l = \frac{y_2 - y_l}{y_2 - y_3} : \frac{y_1 - y_l}{y_1 - y_3},\ \text{as in 6, and}$$

$$\phi_j = x_1 - x_j,\ \text{as in 7.}$$

9. $\left|\overline{q,\ p,\ xp + cyq}\right|$.

The solutions $\psi_j = y_1 - y_j$, $\phi_j = x_1 - x_j$ of the first two equations obtained from this group, when introduced in the last one, give

$$\sum_2^n {}_j \left\{ \phi_j \frac{df}{d\phi_j} + c\, \psi_j \frac{df}{d\psi_j} \right\} = 0.$$

The required invariants of the group may now be chosen as

$$U_k = \frac{x_1 - x_k}{x_1 - x_2},\ V_k = \frac{y_1 - y_k}{y_1 - y_2},\ \sigma = \frac{(x_1 - x_2)^c}{y_1 - y_2},\ (k = 3 \ldots. n).$$

10. $|\overline{q,\ yq,\ p,\ xp}|$.

Comparing this group with 7, we have at once the invariants

$$U_k = \frac{x_1 - x_k}{x_1 - x_2},\ V_k = \frac{y_1 - y_k}{y_1 - y_2},\ (k = 3 \ldots n).$$

11. $|\overline{q,\ yq,\ y^2q,\ p,\ xp}|$.

By comparison with 8 and 10, it will be seen that this five-parameter group leaves invariant

$$\xi_l = \frac{y_2 - y_l}{y_1 - y_l} : \frac{y_2 - y_3}{y_1 - y_3},\ U_k = \frac{x_1 - x_k}{x_1 - x_2},\ (l = 4 \ldots n,\ k = 3, \ldots n).$$

12. $\overline{q,\ yq,\ y^2q,\ p,\ xp,\ x^2p}$.

Comparing with 6, it will be seen that this group leaves invariant the cross-ratios of any four abscissas, and ordinates:

$$\xi_l = \frac{y_2 - y_l}{y_2 - y_3} : \frac{y_1 - y_l}{y_1 - y_3},\ \sigma_l = \frac{x_2 - x_l}{x_2 - x_3} : \frac{x_1 - x_l}{x_1 - x_3},\ (l = 4 \ldots n).$$

13. $|\overline{p + q,\ xp + yq,\ x^2p + y^2q}|$.

This group furnishes the complete system

$$\sum_1^n{}_i \left\{ \frac{df}{dx_i} + \frac{df}{dy_i} \right\} = \sum_1^n{}_i \left\{ x_i \frac{df}{dx_i} + y_i \frac{df}{dy_i} \right\} = \sum_1^n{}_i \left\{ x_i^2 \frac{df}{dx_i} + y_i^2 \frac{df}{dy_i} \right\} = 0.$$

Selecting

$$\phi_j = x_1 - x_j,\ \psi_j = y_1 - y_j,\ \sigma = x_1 - y_1$$

as solutions of the first equation, we have the remaining equations in the form

$$W_1f = \sum_2^n{}_j \left\{ \phi_j \frac{df}{d\phi_j} + \psi_j \frac{df}{d\psi_j} \right\} + \sigma \frac{df}{d\sigma} = 0,$$

$$W_2f = \sum_2^n{}_j \left\{ \phi_j^2 \frac{df}{d\phi_j} + \psi_j^2 \frac{df}{d\psi_j} \right\} + \sigma^2 \frac{df}{d\sigma} = 0.$$

Solutions of $W_1f = 0$ may be taken in the form

$$u_k = \frac{\phi_k}{\phi_2},\ v_k = \frac{\psi_k}{\psi_2},\ \omega_1 = \frac{\phi_2}{\sigma},\ \omega_2 = \frac{\psi_2}{\sigma}.$$

Expressing $W_2f = 0$ in terms of these new variables,

$$\sum_3^n{}_k \left\{ u_k(1 - u_k) \frac{df}{du_k} + v_k(1 - v_k) \frac{df}{dv_k} \right\} + \omega_1(1 - \omega_1) \frac{df}{d\omega_1} + \omega_2(1 - \omega_2) \frac{df}{d\omega_2} = 0.$$

We may choose the solutions of this last equation as the cross-ratios

$$r_l = \frac{u_l(1-u_3)}{u_3(1-u_l)} = \frac{x_2-x_l}{x_2-x_3} : \frac{x_1-x_l}{x_1-x_3},\ \sigma_l = \frac{v_l(1-v_3)}{v_3(1-v_l)} = \frac{y_2-y_l}{y_2-y_3} : \frac{y_1-y_l}{y_1-y_3},$$

$$(l = 4, \ldots n),$$

and the ratios

$$t_1 = \frac{\omega_1(1-\omega_2)}{\omega_2(1-\omega_1)} = \frac{x_1-x_2}{y_1-y_2} : \frac{y_1-x_2}{x_1-y_2},$$

$$t_2 = \frac{u_3(1-v_3)}{v_3(1-u_3)} = \frac{x_1-x_3}{x_2-x_3} : \frac{y_1-y_3}{y_2-y_3},$$

$$t_3 = \frac{u_3(1-\omega_1)}{\omega_1(1-u_3)} = \frac{x_1-x_3}{x_2-x_3} : \frac{x_1-x_2}{y_1-x_2}.$$

SECTION II. INVARIANTS OF SUCH IMPRIMITIVE GROUPS AS LEAVE UNCHANGED ONE FAMILY OF ∞' CURVES.

The remaining groups of the imprimitive type leave invariant one family of ∞' curves, and have been reduced by Lie* to such canonical forms that this invariant family is $x = \text{const.}$

14. $\left| X_1 q,\ X_2 q,\ X_3 q,\ \ldots\ldots X_r q \right|$.

In this group X_k is a function of x alone, and $r > 1$. Each curve of the family $x = \text{const.}$ remains singly invariant.

The complete system of linear partial differential equations

$$W_k f \equiv \sum_1^n {}_i\, X_k(x_i) . \frac{df}{dy_i} = 0,\ (k = 1 \ldots . r),$$

corresponding to this group, has as solutions $x_1, x_2, \ldots x_n$ and $n - r$ other independent functions D_s, $(s = 1, 2 \ldots n - r)$, which we shall define as the $n - r$ determinants of the matrix

$$\left\| \begin{matrix} y_1 & y_2 & \cdots & y_{r+s} & \cdots & y_n \\ X_{1(x_1)} & X_{1(x_2)} & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ X_{r(x_1)} & X_{r(x_2)} & \cdots & \cdots & \cdots & \cdots \end{matrix} \right\|, \qquad (M_r)$$

$$n \geqq r + 1$$

* Lie; Math. Annalen, Bd. XVI; Contin. Gruppen, Chap. 13.

formed by filling the $(r+1)$-th column successively by the $(r+1)$, the $(r+2)$, ..., the n-th column. The invariants are clearly x_i and D_s, $(i = 1 \ldots n,$ $s = 1, \ldots n-r)$.

15. $$\boxed{\begin{matrix} X_1q, X_2q, X_3q, \ldots X_{r-1}q, yq \\ r > 2 \end{matrix}}.$$

This group furnishes the complete system

$$W_kf \equiv \sum_1^n i\, X_k(x_i) \cdot \frac{df}{dy_i} = 0,\ Yf \equiv \sum_1^n i\, y_i \cdot \frac{df}{dy_i} = 0.$$

The solutions of $W_kf = 0$ are clearly x_i and the determinants D_s, $(s = 0, 1 \ldots n-r)$, of a matrix (M_{r-1}) constructed similar to (M_r) in 14. $Yf = 0$ requires the ratios $y_i : y_k$ to appear in the final solutions. Hence, we may write as invariants x_i and

$$\xi_t = D_t : D_o,\ (t = 1 \ldots n-r).$$

16. $$\boxed{\begin{matrix} e^{a_kx}q,\ xe^{a_kx}q,\ x^2e^{a_kx}q,\ \ldots\ x^{\zeta_k}e^{a_kx}q,\ p \\ k = 1, \ldots m,\ \sum_1^m k\, \zeta_k + m = r-1,\ r > 2 \end{matrix}}.$$

From this group we obtain

$$W_k^{t_k}f \equiv \sum_1^n i\, (x_i)^{t_k}\, e^{a_kx_i}.\ \frac{df}{dy_i} = 0,\quad Xf \equiv \sum_1^n i\, \frac{df}{dx_i} = 0,\ (t_k = 0, 1, \ldots \zeta_k).$$

The solutions $\varphi_j = x_j - x_1$ of the last equation are also solutions of the system. By dividing the remaining equations, respectively, by $e^{a_kx_1}$, the exponents of e become functions of φ_j. The independent determinants D_s, $(s = 0, 1 \ldots n-r)$, of the matrix (M_{r-1}), formed as indicated in 15, will be solutions. The invariants are, therefore, φ_j and D_s.

17. $$\boxed{\begin{matrix} e^{a_kx}q,\ xe^{a_kx}q,\ x^2e^{a_kx}q,\ \ldots\ x^{\zeta_k}e^{a_kx}q,\ yq,\ p \\ k = 1 \ldots m,\ \sum_1^m k\, \zeta_k + m = r-2,\ r > 3 \end{matrix}}.$$

The complete system given by this group is

$$W_k^{t_k}f \equiv \sum_1^n i\, (x_i)^{t_k}.\, e^{a_kx_i}.\ \frac{df}{dy_i} = 0,\ Yf \equiv \sum_1^n i\, y_i\, \frac{df}{dy_i} = 0,\ Xf \equiv \sum_1^n i\, \frac{df}{dx_i} = 0,$$

$$(t_k = 0, 1 \ldots \zeta_k).$$

As in 16, the functions $\phi_j = x_j - x_1$ are solutions of $Xf = 0$ and of the system. If a matrix be constructed as indicated in 14 and 16, from the coefficients of the first $r-2$ equations, it will be observed that the independent determinants D_s, $(s = -1, 0, 1 \ldots n-r)$, will be linear and homogeneous in y_i with coefficients composed of functions of ϕ_j. D_s will then be solutions of all equations except $Yf = 0$, which requires the ratios of y_i to appear. Hence, the invariants may be written

$$\phi_j = x_j - x_1,\ \zeta_t = D_t : D_{-1},\ (j = 2 \ldots n,\ t = 0, 1 \ldots n - r).$$

18. | $q, xq, x^2q, \ldots x^{r-3}q, p, xp + cyq$ $r > 3$ |.

Here the complete system is

$$W_k f = \sum_1^n {}_i\, x_i^k \frac{df}{dy_i} = 0,\ (k = 0, 1 \ldots r-3),\ Xf = \sum_1^n {}_i \frac{df}{dx_i} = 0,$$

$$Yf = \sum_1^n {}_i \left\{ x_i \frac{df}{dx_i} + c\, y_i \frac{df}{dy_i} \right\} = 0.$$

The solutions of $W_0 f = 0$, $Xf = 0$ are

$$\psi_j = y_1 - y_j,\ \phi_j = x_1 - x_j$$

Yf expressed in terms of ψ, ϕ becomes

$$Y_1 f = \sum_2^n {}_j \left\{ \phi_j \frac{df}{d\phi_1} + c\psi_1 \frac{df}{d\psi_j} \right\} = 0,$$

with solutions

$$u_k = \phi_k : \phi_2,\ v_j = \psi_j : (\phi_j)^c,\ (k = 3 \ldots n).$$

The functions u_k are solutions of the system. We find on introducing u_k and v_j as new variables in Wf, the partial differential equations

$$W_t' f = \frac{df}{dv_2} - \sum_3^n {}_k\, u_k^{t-c} \cdot \frac{df}{dv_k} = 0,\ (t = 1, 2, \ldots r-3),$$

whose solutions may be expressed as determinants D_s of the matrix.

$$\left\| \begin{matrix} v_2 & v_3 & v_4 \ldots\ldots v_{r-3+s} \ldots\ldots v_n \\ 1 & u_3^{1-c} & u_4^{1-c} \ldots\ldots\ldots\ldots \\ \ldots & \ldots & \ldots \\ \ldots & \ldots & \ldots \\ 1 & u_3^{r-3-c} & u_4^{r-3-c} \ldots\ldots\ldots u_n^{r-3-c} \end{matrix} \right\|.$$

Hence, the point-invariants are

$$u_k = \frac{x_1 - x_k}{x_1 - x_2}, \quad D_s, \ (k = 3 \ldots . n, \ s = 1, \ldots . n - r + 2).$$

19. $\left| \begin{array}{c} q, xq, x^2q, \ldots . x^{r-3}q, p, xp + [(r-2)y + x^{r-2}]q \\ r > 2 \end{array} \right|.$

The solutions of the complete system

$$W_k f \equiv \sum_1^n i \ x_i^k \frac{df}{dy_i} = 0, \ (k = 0, 1 \ldots r - 3), \quad Xf \equiv \sum_1^n i \frac{df}{dx_i} = 0,$$

$$Yf \equiv \sum_1^n i \left\{ x_i \frac{df}{dx_i} + [(r-2) y_i + x_i^{r-2}] \frac{df}{dy_i} \right\} = 0,$$

may be obtained in a manner similar to 18. The solutions ϕ_j, ψ_j of $Xf = 0$, $Wf = 0$, introduced as new variables in Yf, give

$$Y'f \equiv \sum_2^n j \left\{ \phi_j \frac{df}{d\phi_j} + [(r-2)\psi_j + \phi_j^{r-2}] . \frac{df}{d\psi_j} \right\} = 0,$$

with solutions

$$u_k = \phi_k : \phi_2, \ v_j = \log \phi_j - \frac{\psi_j}{\phi_j^{r-2}}, \ (k = 3 \ldots \ldots n, \ j = 2, \ldots n).$$

Introducing u_k, v_j as new variables in Wf, and reducing, we find

$$\dot{W}_t f \equiv \frac{df}{dv_2} + \sum_2^n k \ u_k^{(t+2-r)} . \frac{df}{dv_k} = 0, \ (t = 1, \ldots r - 3),$$

whose solutions are u_k and the determinants D_t of a matrix constructed as in 18.

The invariants are, therefore,

$$u_k = \frac{x_1 - x_k}{x_1 - x_2}, \quad D_s, \ (k = 3 \ldots n, \ s = 1, \ldots n - r + 2).$$

20. $\left| \begin{array}{c} q, xq, x^2q, \ldots \ldots x^{r-4}q, yq, p, xp \\ r > 3 \end{array} \right|.$

For this group

$$W_t f \equiv \sum_1^n i \ x_i^t \frac{df}{dy_i} = 0, \ t = 0, 1, \ldots r - 4),$$

$$Yf \equiv \sum_1^n i \ y_i \frac{df}{dy_i} = 0, \quad X_1 f \equiv \sum_1^n i \frac{df}{dx_i} = 0, \quad X_2 f \equiv \sum_1^n i \ x_i \frac{df}{dx_i} = 0.$$

The last two equations show that the ratios of the differences of the x's, say

$$u_k = \frac{x_1 - x_k}{x_1 - x_2}, \ (k = 3, \ldots . n),$$

shall appear in the final solutions. The $n-r+3$ independent determinants D_s, $(s=0, 1 \ldots . n-r+2)$, of the matrix

$$\left|\begin{array}{cccccc} y_1 & y_2 & y_3 & \cdots\cdots & y_{r-2+s} \cdots\cdots & y_n \\ 1 & 1 & 1 & \ldots\ldots & 1 \ldots\ldots & 1 \\ x_1 & x_2 & x_3 & \ldots\ldots & x_{r-2+s} \ldots\ldots & x_n \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ x_1^{r-4} & x_2^{r-4} & x_3^{r-4} & \ldots & x_{r-2+s}^{r-4} \ldots & x_n^{r-4} \end{array}\right|$$

are solutions of the first $r-3$ equations $W_k f=0$. These determinants are, at the same time, homogeneous in y_i and in $x_i - x_k$; their ratios will, therefore, satisfy the requirements of u_k and $Yf=0$. Hence, we may write our $2n-r$ invariants as $u_k = (x_1 - x_k):(x_1 - x_2)$ and $R_t = D_t : D_o$, $(k=3 \ldots n, t=1 \ldots n-r+2)$.

21. $\boxed{q, xq, x^2q, \ldots . x^{r-4}q, p, 2xp+(r-4)yq, x^2p+(r-4)xyq \quad r>4}$.

From this group we obtain the differential equations

$$W_t f = \sum_1^n {}_i\, x_i^t \frac{df}{dy_i} = 0, \ (t=0, 1 \ldots r-4), \ Xf = \sum_1^n {}_i \frac{df}{dx_i} = 0.$$

$$X_1 f = \sum_1^n {}_i \left\{ 2x_i \frac{df}{dx_i} + (r-4)\, y_i \frac{df}{dy_i} \right\} = 0,$$

$$X_2 f = \sum_1^n {}_i \left\{ x_i^2 \frac{df}{dx_i} + (r-4)\, x_i y_i \frac{df}{dy_i} \right\} = 0.$$

The solutions of $W_0 f=0$, $Xf=0$ are $\psi_j = y_1 - y_j$, $\phi_j = x_1 - x_j$, respectively. $X_2 f$ when expressed in these new variables becomes

$$X_2' f = \sum_2^n {}_j \left\{ \phi_j^2 \frac{df}{d\phi_j} + (r-4)\, \phi_j \psi_j \frac{df}{d\psi_j} \right\} = 0,$$

whose solutions may be selected in the forms

$$u_k = \frac{1}{\varphi_2} - \frac{1}{\varphi_k}, \ v_j = \frac{\psi_j}{\varphi_j^{r-4}}, \ (k=3 \ldots . n, \ j=2 \ldots . n).$$

$$X_1' f = 2 \sum_3^n {}_k\, u_k \frac{df}{du_k} + (r-4) \sum_2^n {}_j\, v_j \frac{df}{dv_j} = 0$$

has solutions

$\sigma_l = u_l : u_3$, $\zeta_k = v_k : u_k^{\frac{1}{2}(r-4)}$, $\zeta_2 = v_2 : u_3^{\frac{1}{2}(r-4)}$, $(k=3 \ldots . n, \ l=4 \ldots . n)$.

The remaining equations W f may be expressed in terms of σ, ζ in the following forms:

$$\frac{df}{d\zeta_2} + \frac{df}{d\zeta_3} + \sum_4^n l \, (\sigma_l)^{-d} \cdot \frac{df}{d\zeta_l} = 0, \; [d = \tfrac{1}{2}(r-4)],$$

$$W_t' f \equiv \frac{df}{d\zeta_3} + \sum_4^n l \, (\sigma)^{t-d} \cdot \frac{df}{d\zeta_l} = 0, \; (t = 1, \ldots r-5).$$

The solutions of these equations may be expressed as the determinants D_s, $(s = 1, \ldots n - r + 3)$, of the matrix

$$\left\| \begin{matrix} \zeta_2 & \zeta_3 & \zeta_4 & \ldots & \zeta_{r-3+s} & \ldots & \zeta_n \\ 1 & 1 & \sigma_4^{-d} & \ldots & \sigma_{r-3+s}^{-d} & \ldots & \sigma_n^{-d} \\ 0 & 1 & \sigma_4^{1-d} & \ldots & \ldots & \ldots & \ldots \\ \ldots & \ldots & \ldots & \ldots & \ldots & \ldots & \ldots \\ \ldots & \ldots & \ldots & \ldots & \ldots & \ldots & \ldots \\ 0 & 1 & \sigma_4^{r-5-d} & \ldots & \ldots & \ldots & \ldots \end{matrix} \right\|.$$

The required invariants are, therefore,

$$\sigma_l = \frac{x_2 - x_l}{x_1 - x_l} : \frac{x_2 - x_3}{x_1 - x_3}, \; D_s, \; (l = 4 \ldots n, \; s = 1, \ldots n - r + 3).$$

22. $q, xq, x^2q, \ldots\ldots x^{r-5}q, yq, p, xp, x^2p + (r-5)\,xyq$; r > 5.

This group furnishes the system

$$W_t f \equiv \sum_1^n i \, x_i^t \frac{df}{dy_i} = 0, \; (t = 0, 1 \ldots r-5), \quad Yf \equiv \sum_1^n i \, y_i \frac{df}{dy_i} = 0,$$

$$Xf \equiv \sum_1^n i \frac{df}{dx_i} = 0, \quad X_1 f \equiv \sum_1^n i \, x_i \frac{df}{dx_i} = 0,$$

$$X_2 f \equiv \sum_1^n i \left\{ x_i^2 \frac{df}{dx_i} + (r-5)\, x_i y_i \frac{df}{dy_i} \right\} = 0.$$

The solutions of $W_0 f = 0$ are $\psi_j = y_1 - y_j$, those of $X_1 f = 0$, $Xf = 0$ are $u_k = (x_1 - x_k) : (x_1 - x_2)$. $X_2 f$ expressed in ψ, u is

$$X_2^1 f = \sum_3^n k \left\{ u_k (u_k - 1) \frac{df}{du_k} + (r-5)\, u_k \cdot \frac{df}{d\psi_k} \right\} + (r-5)\, \psi_2 \frac{df}{d\psi_2} = 0,$$

whose solutions are

$$\sigma_l = \frac{u_3 (u_l - 1)}{u_l (u_3 - 1)}, \; \zeta_k = \frac{\psi_k}{(u_k - 1)^{r-5}}, \; \zeta_2 = \psi_2 \left(\frac{u_3}{u_3 - 1} \right)^{r-5}, \; (l = 4 \ldots n, \; k = 3 \ldots n).$$

The remaining equations expressed in these new variables are

$$\left.\begin{aligned} &\frac{df}{d\zeta_2}+\frac{df}{d\zeta_3}+\sum_4^n l\,(\sigma_l)^{5-r}.\ \frac{df}{d\zeta_l}=0,\\ &W_t^1f\equiv\frac{df}{d\zeta_3}+\sum_4^n l\,(\sigma_l)^{-t}.\ \frac{df}{d\zeta_l}=0,\ (t=1\ \ldots.\ r-5),\end{aligned}\right\}\quad(1)$$

$$Y^1f\equiv\sum_2^n j\ \zeta_j.\ \frac{df}{d\zeta_j}=0.$$

The determinants D_s ($s=0, 1 \ldots. n-r+3$), of the matrix formed from equations (1) as in 21 will be solutions of (1). D_s will be linear in ζ, but $Y^1f=0$ requires the ratios of ζ's. We may write our invariants as

$$\sigma_l=\frac{x_2-x_l}{x_1-x_l}:\frac{x_2-x_3}{x_1-x_3},\ R_t=D_t:D_o,\ (l=4\ \ldots.\ n,\ t=1\ \ldots.\ n-r+3).$$

23. | $p,\ 2xp+yq,\ x^2p+xyq.$ |

This projective group, leaving invariant the x-axis, furnishes us the complete system

$$\sum_1^n i\ \frac{df}{dx_i}=\sum_1^n i\left\{2x_i\frac{df}{dx_i}+y_i\frac{df}{dy_i}\right\}=\sum_1^n i\left\{x_i^2\frac{df}{dx_i}+x_iy_i\frac{df}{dy_i}\right\}=0.$$

The first of these equations has solutions y_i and $\phi_j=x_1-x_j$. The last equation then becomes

$$\sum_2^n j\left\{\phi_j^2\frac{df}{d\phi_j}+y_j\phi_j\frac{df}{dy_j}\right\}=0,$$

with solutions

$$u_k=\frac{1}{\varphi_2}-\frac{1}{\varphi_k},\ v_j=\frac{\phi_j}{y_j},\ y_1.$$

The second equation is now

$$y_1\frac{df}{dy_1}+\sum_2^n j\ \ v_j\frac{df}{dv_j}-2\sum_3^n k\ \ u_k\frac{df}{du_k}=0,$$

whose solutions we may choose in the forms

$$\delta_l=\frac{u_l}{u_3},\ \zeta_k=\frac{v_k}{v_2},\ \zeta_2=\frac{v_2}{y_1},\ \zeta_1=y_1v_2u_3,\ (l=4\ \ldots.\ n,\ k=3\ \ldots.\ n).$$

Our invariants are

$$\delta_l=\frac{x_2-x_l}{x_2-x_3}:\frac{x_1-x_l}{x_1-x_3},\ \zeta_k=\frac{x_1-x_k}{x_1-x_2}:\frac{y_k}{y_2},\ \zeta_2=\frac{{}_1x-x_2}{y_1y_2},\ \zeta_1=\frac{x_2-x_3}{x_1-x_3}:\frac{y_2}{y_1},$$

whose geometric significance is apparent.

24. | $yq,\ p,\ xp,\ x^2p+nyq$ |.

This four-parameter projective group yields the complete system

$$\sum_1^n i\, y_i \frac{df}{dy_i} = \sum_1^n i \frac{df}{d\mathbf{x}_i} = \sum_1^n i\, x_i \frac{df}{d\mathbf{x}_i} = \sum_1^n i \left\{ x_i^2 \frac{df}{dx_i} + x_i y_i \frac{df}{dy_i} \right\} = 0.$$

Here, we introduce the solutions

$$\phi_j = \mathbf{x}_1 - \mathbf{x}_j,\ \psi_j = \frac{y_j}{y_1},$$

of the first two equations in the last two, and have

$$\sum_2^n j\ \phi_j \frac{df}{\sigma\phi_j} = \sum_2^n j \left\{ \phi_j^2 \frac{df}{\sigma\phi_j} + \phi_j \psi_j \frac{df}{\phi\psi_j} \right\} = 0.$$

The last of these new equations is satisfied by

$$u_k = \frac{1}{\rho_1} - \frac{1}{\rho_k},\ v_j = \frac{\phi_j}{\psi_j},\ (k = 3 \ldots . n,\ j = 2 \ldots . n);$$

the first now becomes

$$\sum_3^n k\ u_k \frac{df}{du_k} - \sum_2^n j\ v_j \frac{df}{dv_j} = 0.$$

The solutions of this equation are the requred invariants:

$$\sigma_l = \frac{u_l}{u_3} = \frac{x_2 - x_l}{x_2 - x_3} : \frac{x_1 - x_l}{x_1 - x_3},\ (l = 4 \ldots . n),$$

$$\tau_k = \frac{v_k}{v_2} = \frac{x_1 - x_k}{x_1 - x_2} : \frac{y_k}{y_2},\ (k = 3 \ldots . n),$$

$$\omega = u_3 v_2 = \frac{x_2 - x_3}{x_1 - x_3} : \frac{y_2}{y_1}.$$

SECTION III. INVARIANTS OF THE PRIMITIVE GROUPS.

The remaining finite continuous groups of the plane leave *no* family of ∞' curves invariant, and may be reduced by a proper choice of variables to some one of the canonical forms known as (1) special linear, (2) general linear, (3) general projective.*

25. *The special linear group*

$$\boxed{p,\ q,\ xq,\ xp - yq,\ yp}\ .$$

The invariant functions of the coördinates of n points will be the $2n - 5$ independent solutions of the complete system

$$\sum_1^n j \frac{df}{d\mathbf{x}_i} = \sum_1^n i \frac{df}{dy_i} = \sum_1^n i\ x_i \frac{df}{dy_i} = \sum_1^n i \left\{ x_i \frac{df}{dx_i} - y_i \frac{df}{dy_i} \right\} = \sum_1^n i\ y_i \frac{df}{d\mathbf{x}_i} = 0. \quad (1)$$

*Lie: Math. Annalen, Bd. XVI, p. p. 518-522, also Contin. Gruppen, p. 351.

The first two equations show the solutions of the system to be functions of

$$\phi_j = x_1 - x_j,\ \psi_j = y_1 - y_j,\ (j = 2 \ldots n).$$

The remaining equations then take the forms

$$\sum_2^n{}_j\, \phi_j \frac{df}{d\psi_j} = \sum_2^n{}_j \left\{ \phi_j \frac{df}{d\phi_j} - \psi \frac{df}{d\psi_j} \right\} = \sum_2^n{}_j\, \psi_j \frac{df}{d\phi_j} = 0. \quad \ldots\ldots\ldots (2)$$

The second of these equations has solutions

$$u_j = \phi_j \psi_j,\ v_k = \phi_2 \psi_k,\ (k = 3 \ldots n).$$

With u and v as new variables, the first and third of equations (2) become

$$\frac{df}{du_2} + \sum_3^n{}_k \left\{ \frac{u_k^2}{v_k^2} \frac{df}{du_k} + \frac{u_k}{v_k} \frac{df}{dv_k} \right\} = 0, \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$u_2 \frac{df}{du_2} + \frac{1}{u_2} \sum_3^n{}_k\, v_k^2 \frac{df}{u_k} + \frac{1}{v_3} \sum_3^n{}_k\, v_k \frac{df}{dv_k} = 0. \quad \ldots\ldots (4)$$

The solutions of (3) are found to be

$$\sigma_k = \frac{v_k}{u_k},\ \zeta_k = u_2 - \frac{v_k^2}{u_k}.$$

Equation (4) then reduces to

$$\sum_3^n{}_k \left\{ \sigma_k \zeta_k \frac{df}{d\sigma_k} + \zeta_k^2 \frac{df}{d\zeta_k} \right\} - 0,$$

whose solutions may be written

$$I'_k = \frac{\zeta_k}{\sigma_k},\ J_l = \frac{1}{\zeta_l} - \frac{1}{\zeta_3},\ (k = \ldots n,\ l = 4 \ldots n).$$

Since any functions of I′, J will be the solutions of (1), we may choose

$$I'_k = \frac{\zeta_k}{\sigma_k} = \left| 1\ 2\ k \right| \text{ and } D_l = J_l\, I_3'\, I_l' = \left| 1\ 3\ l \right|,$$

$$\text{where } \left| i\ j\ k \right| = \begin{vmatrix} x_i & y_i & 1 \\ x_j & y_j & 1 \\ x_k & y_k & 1 \end{vmatrix},$$

as solutions, and, therefore, as the 2 n — 5 invariants of the group.

The forms of I′ and D show that *the special linear group leaves invariant all areas.*

26. *The general linear group*

$$\left| \overline{p,\ q,\ xq,\ xp - yq,\ yp,\ xp + yq} \right|.$$

This group furnishes a complete system of six linear partial differential equations, the first five of which are identical with equations (1) of the preceding section. Hence we need only determine the functions of I′ and D which satisfy

$$\sum_1^n{}_i \left\{ x_i \frac{df}{dx_i} + y_i \frac{df}{dy_i} \right\} = 0.$$

This equation requires x, y to enter in the final solutions to the degree zero. Hence, we may write at once the invariants in the form

$$I_l = \frac{I_l'}{I_3'} = | \ 1 2 l \ | : | \ 1 2 3 \ | ,$$

$$J_l = \frac{D_l}{I_3} = | \ 1 3 l \ | : | \ 1 2 3 \ | , (l = 4 \ldots . n).$$

I and J show that by *the general linear group the ratio of areas remains constant.*

27. *The general proejctive group*

$$\left| \, p, \, q, \, xq, \, xp - yq, \, yp, \, xp + yq, \, x^2p + xyq, \, xyp + y^2q \, \right|.$$

The members of this group extended and equated to zero furnish a complete system of eight linear partial differential equations, the first six of which are identical with those of the general linear group, and therefore have solutions I, J, defined in 26. The last two equations,

$$\sum_1^n i \left\{ x_i^2 \frac{df}{dx_i} + x_i y_i \frac{df}{dy_i} \right\} = \sum_1^n i \left\{ x_i y_i \frac{df}{dx_i} + y_i^2 \frac{df}{dy_i} \right\} = 0,$$

when expressed in terms of I, J, become somewhat complex, viz.:

$$(1) \quad J_4 (I_4 - J_4 - 1) \frac{df}{dJ_4} + \sum_5^n m \left\{ I_m (I_4 J_m - I_m J_4 - J_m + J_4) \frac{df}{dI_m} + \right.$$

$$\left. J_m (I_4 J_m - I_m J_4 - J_m + I_4 - 1) \frac{df}{dJ_m} \right\} = 0.$$

$$(2) \quad I_4 \ (J_4 - I_4 + 1) \frac{df}{dI_4} + \sum_5^n m \left\{ J_m (I_4 J_m - I_m J_4 - I_m + I_4) \frac{df}{dJ_m} + \right.$$

$$\left. I_m (I_4 J_m - I_m J_4 - I_m + J_4 + 1) \frac{df}{dI_m} \right\} = 0.$$

After considerable manipulation, the solutions of (1) are found to be

$$I_4, \ \varphi_m = \frac{I_m J_4}{J_m}, \ \psi_m = \frac{\varphi_m + I_m (I_4 - \varphi_m - 1)}{I_m (J_4 - I_4 + 1)}, \quad (m = 5 \ldots . n) \cdot$$

With I_4, φ_m, ψ_m as new variables, equation (2) becomes

$$I_4 \frac{df}{dI_4} + \sum_5^n m \ \varphi_m \frac{df}{d\varphi_m} = 0,$$

with solutions

$$Q_m = \frac{\varphi_m}{I_4}, \ \psi_m \cdot$$

Selecting as invariants Q_m and $H_m = \frac{1 + \psi_m}{Q_m}$, and restoring the variables $x_i\, y_i$, we have

$$Q_m = \frac{|\,1\,2\,m\,|}{|\,1\,2\,4\,|} : \frac{|\,1\,3\,m\,|}{|\,1\,3\,4\,|}, \quad H_m = \frac{|\,1\,2\,4\,|}{|\,1\,2\,m\,|} : \frac{|\,2\,3\,4\,|}{|\,2\,3\,m\,|}.$$

The forms of Q and H show that *the general projective group leaves invariant the cross-ratios of five points.*

Differential Invariants Derived from Point-Invariants.

By David A. Rothrock.

In an accompanying article concerning Point-Invariants, the writer has shown how a group

$$X_k f \equiv \xi_k(x, y)\frac{df}{dx} + \eta_k(x, y)\frac{df}{dy}, \quad (k = 1 \ldots r),$$

may be *extended* to include the increments of the coördinates of n points. The members of a group may be *extended* in a different manner, and indeed so as to include the increments of

$$\frac{dy}{dx}, \frac{d^2y}{dx^2}, \frac{d^3y}{dx^3}, \ldots .$$

For example, the group $X_k f$ gives to x and y the increments

$$\delta x = \xi_k \delta t, \; \delta y = \eta_k \delta t,$$

and to $y' = \frac{dy}{dx}$, the increment

$$\delta y' = \frac{dx \, . \, \delta dy - dy \, . \, \delta dx}{dx^2} = \frac{d\eta_k - y' d\xi_k}{dx}\delta t \equiv \eta'_k \delta t.$$

Similarly, $y'' = \frac{d^2y}{dx^2}$ receives the increment

$$\delta y'' = \frac{d\eta'_k - y'' d\xi_k}{dx}\delta t \equiv \eta''_k \delta t,$$

and in general

$$\delta y^{(m)} = \frac{d\eta_k{}^{(m-1)} - y^m d\xi_k}{dx}\delta t \equiv \eta_k{}^{(m)} \delta t.$$

The group $X_k f$ so extended becomes

$$X_k^{(m)} f = \xi_k \frac{df}{dx} + \eta_k \frac{df}{dy} + \eta_k^{(1)} \frac{df}{dy^1} + \eta_k^{(2)} \frac{df}{dy^{(2)}} + \dots + \eta_k^{(m)} \frac{df}{dy^{(m)}}. *$$

Lie has shown that the extended transformations $X_k^{(m)} f$ form an r— parameter group since the *bracket relations*

$$(X_i^{(m)}, X_k^{(m)}) = X_i^{(m)} (X_k^{(m)} f) - X_k^{(m)} (X_i^{(m)} f) \equiv \sum_1^r {}_s\, c_{iks}\, X_s^{(m)} f \dots\dots\dots\dots (1)$$

exist. But when relations (1) hold, the equations

$$X_k^{(m)} f = \xi_k \frac{df}{dx} + \eta_k \frac{df}{dy} + \sum_1^m {}_i\, \eta_k^{(i)} \frac{df}{dy^{(i)}} = 0$$

are known to form a complete system of linear partial differential equations in $2 + m$ variables. This system has at least $2 + m - r$ independent solutions which are defined as the *differential invariants* of the group $X_k f$.

In Lie's paper cited above it is shown that if two independent differential invariants be known, all others may be found by differentiation. For example, if the two fundamental differential invariants be φ_1, φ_2, then

$$\varphi_3 = \frac{d\varphi_2}{d\varphi_1}, \ \varphi_4 = \frac{d\varphi_3}{d\varphi_1}, \dots \dots .$$

The fundamental differential invariants $\varphi_1 (x, y, y_1, y_2, \dots y_{r-1})$, $\varphi_2 (x, y, y_1, y_2, \dots y_r)$, of an r-parameter group may, in general, be obtained from a somewhat different point of view, and indeed without a knowledge of the form of the group itself, provided the point-invariants of the group be known.

Let us suppose the points of a point-invariant $\Theta (x, y, x^{[2]}, y^{[2]} \dots)$ to lie upon a curve $x = f_1 (t)$, $y = f_2 (t)$, where f_1, f_2 are analytic functions of the parameter t. We seek the nature of the invariants when two or more points upon this curve approach coincidence. If x, y be a point for $t = t_0$, then a point $x^{(2)}$, $y^{(2)}$, ultimately coincident with x, y, will be given by

$$x^{(2)} = x + x' dt + x'' \frac{dt^2}{2} + \dots, \ y^{(2)} = y + y' dt + y'' \frac{dt^2}{2} = \dots, \quad \dagger$$

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* Lie: Ueber Differentialgleichungen, die eine Gruppe gestatten. Mathematische Annalen, Bd. XXXII.

† Throughout this paper we shall employ the following notation:

(a) x, y; $x^{(2)}, y^{(2)}$; $x^{(3)}, y^{(3)}$; .... are points of the plane.

(b) $x' = \frac{dx}{dt}$, $x'' = \frac{d^2x}{dt^2}$, ...; $y' = \frac{dy}{dt}$, $y'' = \frac{d^2y}{dt^2}$, ...

(c) $y_1 = \frac{dy}{dx}$, $y_2 = \frac{d^2y}{dx^2}$, ...; hence, we have $y' = y_1 x'$,

$y'' = y_2 (x')^2 + y_1 x''$, $y''' = y_3 (x')^3 + 3y_2 x' x'' + y_1 x'''$, ...

and similarly with other parameters for any number of consecutive points. On substituting these series expansions of $x^{(i)}$, $y^{(i)}$ in Θ, we shall evidently obtain an invariant function. If now Θ be capable of expansion in a power-series with regard to dt, dr, ..., we shall have the coefficients, $I_1(x, y, x', y', \ldots)$, $I_2(x_1 y, x', y', \ldots)$, ..., of the powers of dt, dr, ... separately invariant, since the parameters t, r, ... are arbitrary. In I_1, I_2, I_3 .... we may express $y', y'', y''', \ldots$ as functions of $y_1, y_2, \ldots\; x', x'', x''', \ldots$. If then $I_1, I_2, I_3, \ldots$ may be so combined as to eliminate the differentials $x', x'', x''', \ldots$, we shall obtain invariant functions, $\phi_1(x, y, y_1, y_2, \ldots)$, ϕ_2, ϕ_3, ..., which are *differential invariants* in the sense already defined.

The calculation of differential invariants by the method just outlined is sometimes quite laborious. Below is given a consideration of some of the more characteristic groups.

SECTION I. DIFFERENTIAL INVARIANTS DETERMINED BY TWO POINTS.

In the present section are computed the differential invariants for some of the more simple groups of the plane, and indeed for such as have point-invariants for two distinct points. Only two differential invariants have been determined for each group; all others may be found from these by differentiation.*

1. The group

q

has the point-invariants $x^{(i)}$, $\psi_2 = y - y^{(2)}$. Expressing $y^{(2)}$ in terms of a parameter t, we have ultimately

$$\psi_2 = y - \left(y + y'dt + y''\frac{dt^2}{2} + \ldots\right).$$

Since dt is arbitrary, $y', y'', \ldots$ are singly invariant.

$y' = x'y_1$, but x' as well as x is invariant, hence y_1 is invariant, and our differential invariants may be written

$$\phi_1 = x, \phi_2 = y_1 \cdot$$

2. The group

p, q

has the point-invariants

$$u_2 = x - x^{(2)},\ v_2 = y - y^{(2)}.$$

Hence, we have

$$u_2 = x - \left(x + x'dt + x''\frac{dt^2}{2} + \ldots\right),\quad v_2 = y - \left(y + y'dt + y''\frac{dt^2}{2} + \ldots\right),$$

*Lie: Math. Annalen, Bd. XXXII, p. 220.

which show $x', x'', \ldots, y', y'', \ldots$ to be invariant. But $y' = y_1 x'$, $y'' = y_2(x')^2 + y_1 x''$; hence, y_1, y_2 must each be invariant.

$$\therefore \varphi_1 = y_1, \; \varphi_2 = y_2 .$$

3. The point-invariants of the group

$$\boxed{q, \; xp + yq}$$

are
$$u_2 = \frac{x^{(2)}}{x}, \quad v_2 = \frac{y - y^{(2)}}{x} .$$

Introducing the series expansion of $x^{(2)}, y^{(2)}$,

$$u_2 = \left(x + x'dt + x'' \frac{dt^2}{2} + \ldots\right) : x,$$

$$v_2 = \left\{ y - \left(y + y'dt + y'' \frac{dt^2}{2} + \ldots\right) \right\} : x .$$

u_2 shows the ratios

$$\frac{x'}{x}, \frac{x''}{x}, \frac{x'''}{x}, \ldots \qquad (1)$$

to be invariant, while v_2 requires the invariance of

$$\frac{y'}{x}, \frac{y''}{x}, \frac{y'''}{x}, \ldots\ldots$$

$$I_1 = \frac{y'}{x} = \frac{y_1 x'}{x};$$

hence y_1 is invariant on account of (1).

$$I_2 = \frac{y''}{x} = \frac{y_2 (x')^2 + y_1 x''}{x}, \text{ or } I_2 - \phi_1 \frac{x''}{x} = x y_2 \left(\frac{x'}{x}\right)^2 .$$

Therefore, $\phi_1 = y_1$, $\phi_2 = x y_2$.

4. The group

$$\boxed{p, \; q, \; xp + yq}$$

has the point-invariants

$$u_2 = \frac{y - y^{(2)}}{x - x^{(2)}}, \quad v_3 = \frac{x - x^{(3)}}{x - x^{(2)}} .$$

One differential invariant may be computed from u_2 alone, but a second can not be had on account of impossibility of the elimination of the parameters. We therefore consider three points determined by t, r.

$$u_2 = \left\{ y - \left(y + y' dt + y'' \frac{dt^2}{2} + \ldots\right) \right\} : \left\{ x - \left(x + x' dt + x'' \frac{dt^2}{2} + \ldots\right) \right\}$$

$$= \frac{y'}{x'} + \frac{dt}{2}\left(\frac{y''}{x'} - \frac{y' x''}{(x')^2}\right) + \frac{dt^2}{2}\left(\frac{y' (x'')^2}{2 (x')^3} - \frac{y' x'''}{3 (x')^2} - \frac{y'' x''}{2 (x')^2} + \frac{y''}{3x'}\right) + \ldots,$$

$$v_3 = \left\{x - (x + x' dr + x'' \frac{dr^2}{2} + \ldots.)\right\} : \left\{x - x(+ x' dt + x'' \frac{dt^2}{2} + \ldots.\right\}$$

$$= \frac{dr}{dt} - \frac{dr}{2} \cdot \frac{x''}{x'} - \frac{dr^2}{4}\left(\frac{x''}{x'}\right)^2 + dt\, dr \left\{\left(\frac{x''}{2x'}\right)^2 - \frac{x'''}{6x'}\right\} + \ldots\ldots.$$

These functions show

$$\frac{x''}{x'},\ I_1 = \frac{y'}{x'} = y_1,\ I_2 = \frac{y''}{x'} - \frac{y'x''}{(x')^2} = y_2\, x',\ \text{and}$$

$$I_3 = \frac{y'''}{3\,x'} - \frac{y''\,x''}{2\,(x')^2} - \frac{y'\,x'''}{3\,(x')^2} + \frac{y'\,(x'')^2}{2\,(x')^3} = \frac{y_3\,(x')^3}{3} + \frac{y_2 x''}{2}$$

to be invariant. Eliminating the parameters x′, x″, we have

$$\left\{I_3 \div I_2 - \frac{x''}{2x'}\right\} \div I_2 = \frac{y_3}{3\,(y_2)^2}.$$

$$\therefore \varphi_1 = y_1,\ \phi_2 = \frac{y_3}{{y_2}^2}.$$

SECTION II. DIFFERENTIAL INVARIANTS DETERMINED BY THREE OR MORE POINTS.

In the case of the more complex groups it is necessary to bring into consideration three, four, five, ... points, and consequently employ additional parameters, r, s, ...

5. For three points, the group

$$\overline{\underline{p,\ q,\ xp + cyq}}$$

possesses the point-invariants

$$u = \frac{y - y^{(2)}}{(x - x^{(2)})^c},\quad v_3 = \frac{x - x^{(3)}}{x - x^{(2)}},\quad w_3 = \frac{y - y^{(3)}}{y - y^{(2)}}.$$

Expressing u, in series expansion for $x^{(2)}$, $y^{(2)}$, we have

$$u = \frac{y - (y + y'dt + y''\frac{dt^2}{2} + .)}{\left\{x - (x + x'dt + x''\frac{dt^2}{2} + ..)\right\}^c}$$

$$= \frac{k}{(x')^c}\left\{y' + \frac{dt}{2}\left[y'' - cy'\frac{x''}{x'}\right] + \right.$$

$$\left. dt^2\left[\frac{y'''}{6} - \frac{cy''}{4}\cdot\frac{x''}{x'} + y'\left(l\left(\frac{x''}{x'}\right)^2 - \frac{c}{6}\frac{x'''}{x'}\right)\right]\ldots\right\}.$$

The series expansion of v_3 is identical with that of v_3 in 4 above. Hence, the invariant functions may be written

$$\frac{x''}{x'}, \frac{x'''}{x'}, \frac{x^{iv}}{x'}, \ldots, I_1 = \frac{y'}{(x')^c} = \frac{y_1}{(x')^{c-1}}, \; I_2 = \frac{y''}{(x')^c} - cy' \frac{x''}{(x')^{c+1}} =$$

$$\frac{y_2}{(x')^{c-2}} \quad h \, . \, I_1 \frac{x''}{x'},$$

$$I_3 = \frac{y'''}{6\,(x')^c} - \frac{cy''}{4\,(x')^c} \cdot \frac{x''}{x'} + \frac{y'}{(x')^c}\left\{ l \left(\frac{x''}{x'}\right)^2 - \frac{c}{6} \cdot \frac{x'''}{x'} \right\}$$

$$k_1 \frac{y_3}{(x')^{c-3}} + k_2 \frac{x''}{x'} \cdot \frac{y_2}{(x')^{c-2}} + \left\{ k_3, \frac{x'''}{x'} + k_4 \left(\frac{x''}{x'}\right)^2 \right\} \frac{y_1}{(x')^{c-1}}$$

From these relations follows at once the invariance of

$$\frac{y_1}{(x')^{c-1}}, \; \frac{y_2}{(x')^{c-2}}, \; \frac{y_3}{(x')^{c-3}}.$$

By eliminating x', we have

$$\frac{y_2}{y_1^{\frac{c-2}{c-1}}}, \quad \varphi_2 \quad \frac{y_3}{y_1^{\frac{c-3}{c-1}}}.$$

6. q, yq leaves invariant x and $v_3 = \frac{y - y^{(3)}}{y - y^{(2)}}$. Expanding v_3 in series,

$$v_3 = \left\{ y - \left(y + y' dr + y'' \frac{dr^2}{2} \ldots\right) \right\} : \left\{ y - \left(y + y' dt + y'' \frac{dt^2}{2} + \ldots\right) \right\}$$

$$= \frac{dr}{dt} - \frac{dr}{2} \frac{y''}{y'} - dr^2 \left(\frac{y''}{2y'}\right)^2 + \ldots,$$

which gives invariant functions $\frac{y''}{y'}, \frac{y'''}{y'}, \ldots$. The functions $x, x', x'' \ldots$ are also invariant.

$$I_1 = \frac{y''}{y'} = \frac{y_2}{y_1} x' + \frac{x''}{x'}.$$

$$\therefore \varphi_1 = x, \; \varphi_2 = \frac{y_2}{y_1}.$$

7. The group

$$q, yq, p$$

has point-invariants

$$u_2 = x - x^{(2)}, \; v_3 = \frac{y - y^{(3)}}{y - y^{(2)}}.$$

We have, as in 6, the invariant functions

$$x',\ x'',\ x''',\ \ldots,\ I_1 = \frac{y''}{y'} = \frac{y_2 x'}{y_1} + \frac{x''}{x'},$$

$$I_2 = \frac{y'''}{y'} = \frac{y_3 (x')^2}{y_1} + 3\,\frac{y_2 x''}{y'} + \frac{x'''}{x'}.$$

$$\therefore \phi_1 = \frac{y_2}{y_1},\quad \phi_2 = \frac{y_3}{y_1}.$$

8. The point-invariants of the four-parameter group

$$\boxed{p,\ xp,\ q,\ yq}$$

are
$$u_3 = \frac{x - x^{(3)}}{x - x^{(2)}},\quad v_3 = \frac{y - y^{(3)}}{y - y^{(2)}}.$$

The series expansion for u_3, v_3 in powers of dt, dr will be identical with those for v_3 in 4 and 7, respectively. Hence, we have the invariant differential functions

$$\frac{x''}{x'},\ \frac{x'''}{x'},\ \frac{x^{iv}}{x'},\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots,\ (1),$$

and

$$I_1 = \frac{y''}{y'} = \frac{y_2 x'}{y_1} + \frac{x''}{x'},\quad I_2 = \frac{y'''}{y'} = \frac{y_3 (x')^2}{y_1} + 3\frac{y_2 x'}{y_1}\cdot\frac{x''}{x'} + \frac{x'''}{x'},$$

$$I_3 = \frac{y^{iv}}{y'} = \frac{y_4 (x')^3}{y_1} + \frac{6\,y_3 (x')^2}{y_1}\cdot\frac{x''}{x'} + \frac{y_2 x'}{y_1}\left\{3\left(\frac{x''}{x'}\right)^2 + 4\,\frac{x'''}{x'}\right\} + \frac{x^{iv}}{x'}.$$

Hence, on account of (1), we have the invariant functions

$$\frac{y_2 x'}{y_1},\ \frac{y_3 (x')^2}{y_1},\ \frac{y_4 (x')^3}{y_1},$$

from which it is only necessary to eliminate x' in order to obtain our required differential invariants:

$$\phi_1 = \frac{y_1 y_3}{y_2^{\,2}},\quad \phi_2 = \frac{y_4 y_1^{\,2}}{y_2^{\,3}}.$$

9. The general projective group in one variable

$$\boxed{q,\ yq,\ y^2 q}$$

leaves invariant x and $R = \dfrac{y^{(2)} - y^{(4)}}{y - y^{(4)}} : \dfrac{y^{(2)} - y^{(3)}}{y - y^{(3)}}$.

Using t, r, s as auxiliary variables, R takes the form, for ultimately coincident points

$$R = \frac{1 - \alpha}{1 - \beta} = (1 - \alpha)\,(1 + \beta + \beta^2 + \ldots),$$

where $a = (y' \, dt + y'' \frac{dt^2}{2} + \ldots .) : (y' ds + y'' \frac{ds^2}{2} + \ldots .)$, and

$$\beta = (y' \, dt + y'' \frac{dt^2}{2} + \ldots .) : (y' \, dr + y'' \frac{dr^2}{2} + \ldots .).$$

Arranging R according to positive powers of dt, dr, ds, and omitting superfluous terms, we find

$$R \equiv \ldots . \, dt \, (ds - dr) \left\{ \frac{y'''}{6y'} - \left(\frac{y''}{2y'} \right)^2 \right\} + \ldots .$$

$$+ \, dt \, (ds^2 - dr^2) \left\{ \frac{y^{iv}}{24y'} - \frac{y'' \, y'''}{6 \, (y')^2} + \left(\frac{y''}{2y'} \right)^3 \right\} + \ldots .$$

$$+ \, dt \, (ds^3 - dr^3) \left\{ \frac{y^{v}}{120y'} - \frac{y'' \, y^{iv}}{24 \, (y')^2} - \left(\frac{y'''}{6y'} \right)^2 - \left(\frac{y''}{2y'} \right)^4 + \frac{(y'')^2 \, y'''}{8 \, (y')^3} \right\} + \ldots$$

From these coefficients we may determine the differential invariants.

$\phi_1 = x.$

$$I_1 = \frac{y'''}{6y'} - \left(\frac{y''}{2y'} \right)^2 = \frac{(x')^2}{12} \, \frac{2y_1 \, y_3 - 3y_2^{\,2}}{y_1^{\,2}} + \frac{x'''}{6x'} - \left(\frac{x''}{2x'} \right)^2,$$

$$\therefore \phi_2 = \frac{2y_1 \, y_3 - 3y_2^{\,2}}{y_1^{\,2}}.$$

$$I_2 = \frac{(x')^3}{24} \left(\frac{y_4}{y_1} - \frac{4y_2 \, y_3}{y_1^{\,2}} + \frac{3y_2^{\,3}}{y_1^{\,3}} \right) + \frac{x' \, x''}{24} \, \phi_2 + I_2 \, (x),$$

$$\therefore \phi_3 = \frac{y_4}{y_1} - 4 \, \frac{y_2 \, y_3}{y_1^{\,2}} + 3 \, \frac{y_2^{\,3}}{y_1^{\,3}}.$$

$$I_3 = \frac{(x')^4}{120} \left(\frac{y_5}{y_1} - 5 \, \frac{y_2 \, y_4}{y_1^{\,2}} - 4 \, \frac{y_3^{\,2}}{y_1^{\,2}} + 17 \, \frac{y_2^{\,2} \, y_3}{y_1^{\,3}} - 9 \, \frac{y_2^{\,4}}{y_1^{\,4}} \right) +$$

$$+ \frac{(x')^2 \, x''}{24} . \, \phi_3 + \frac{(x')^4}{720} \, \phi_2^{\,2} + \frac{x' \, x'''}{72} \, \phi_2 + I_3 \, (x),$$

$$\therefore \phi_4 = \frac{y_5}{y_1} - 5 \, \frac{y_2 \, y_4}{y_1^{\,2}} - 4 \left(\frac{y_3}{y_1} \right)^2 + 17 \, \frac{y_2^{\,2} \, y_3}{y_1^{\,3}} - 9 \left(\frac{y_2}{y_1} \right)^4.$$

In some of the following paragraphs we shall need the forms I_2, I_3, here computed. Incidentally we have computed the differential invariants ϕ_3, ϕ_4.

10. The group

$$| \; q, \, yq, \, y^2q, \, p$$

has the same differential invariants as 9 above, with the exception of ϕ_1, which must be omitted. We shall have, therefore, ϕ_2, ϕ_3, ϕ_4, as defined above.

11. By the group

$$q,\ yq,\ y^2q,\ p,\ xp$$

the functions I_1, I_2, I_3 of 9 remain invariant, also $\frac{x''}{x'}$, $\frac{x'''}{x'}$, $\frac{x^{iv}}{x'}$, ... as in 8. These invariant functions must be so manipulated that the x's are either eliminated or made to appear as ratios $\frac{x''}{x'}$, $\frac{x'''}{x'}$, ... Since $I_1(x)$, $I_2(x)$ .... are already functions of $\frac{x''}{x'}$, $\frac{x'''}{x'}$, ..., we may omit these, and write simply

$$J_1 = \phi_2(x')^2,\ J_2 = \varphi_3(x')^3 + \phi_2 x'x'',$$

$$J_3 = \varphi_4 \frac{(x')^4}{5} + \varphi_3(x')^2x'' + \phi_2{}^2 \frac{(x')^4}{30} + \phi_2 \frac{x'x'''}{3}.$$

Eliminating x', x'', ... ,

$$\left\{J_2 : J_1 - \frac{x''}{x'}\right\} : (J_1)^{\frac{1}{2}} \equiv \frac{\phi_3}{(\varphi_2)^{\frac{3}{2}}} = \frac{\frac{y_4}{y_1} - \frac{4y_2 y_3}{y_1{}^2} + 3\left\{\frac{y_2}{y_1}\right\}^3}{\left\{\frac{2y_3}{y_1} - 3\left\{\frac{y_2}{y_1}\right\}^2\right\}^{\frac{3}{2}}} = \Phi_1 .$$

$$J_3 : J_1 \equiv \frac{\phi_4}{\varphi_2} \cdot \frac{(x')^2}{5} + \frac{\varphi_3}{\varphi_2} x' \left\{\frac{x''}{x'}\right\} + \phi_2 \frac{(x')^2}{30} + \frac{x'''}{3x'}$$

$$= \frac{\phi_4}{\varphi_2} \cdot \frac{(x')^2}{5} + \left\{J_2 : J_1 - \frac{x''}{x'}\right\} \frac{x''}{x'} + \frac{J_1}{30} + \frac{x'''}{3x'} .$$

Hence, $A \equiv \frac{\phi_4}{\varphi_2} (x')^2$ is invariant.

$$A : J_1 = \frac{\phi_4}{\phi_2{}^2} = \frac{\frac{y_5}{y_1} - 5\frac{y_2 y_4}{y_1{}^2} - 4\left\{\frac{y_3}{y_1}\right\}^2 + 17\frac{y_2{}^2 y_3}{y_1{}^3} - 9\left\{\frac{y_2}{y_1}\right\}^4}{\left\{\frac{2y_3}{y_1} - 3\left\{\frac{y_2}{y_1}\right\}^2\right\}^2} = \Phi_2 .$$

Φ_1, Φ_2 are the two fundamental differential invariants.

12. It has been shown that the group

$$X_1(x)\, q,\ X_1(x) . q,\ X_3(x)\, q,\ \dots .\ X_r(x) . q \qquad r > 1$$

leaves invariant x and the determinant

$$D = \begin{vmatrix} y & y^{(2)} & y^{(3)} & \dots\dots & y^{(r+1)} \\ X_1(x) & X_1(x^{(2)}) & X_1(x^{(3)}) & \dots\dots & X_1(x^{(r+1)}) \\ \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots \\ X_r(x) & X_r(x^{(2)}) & X_r(x^{(3)}) & \dots\dots & X_r(x^{(r+1)}) \end{vmatrix} .$$

We shall denote the parameters for $x^{(2)}$, $x^{(3)}$ .... by t, s, ..., respectively, and have series expansion for $X_i(x^{(2)})$ in the form

$$X_i(x^{(2)}) = X_i(x + x'dt + x''\frac{dt^2}{2} + x'''\frac{dt^3}{6} + ..)$$

$$= X_i(x) + X_i'(x).x'dt + \left\{X_i''(x).x'^2 + X_i'(x).x''\right\}\frac{dt^2}{2} +$$

$$+ \left\{X_i'''(x).x'^3 + 3X_i''(x).x'x'' + X_i'(x).x'''\right\}\frac{dt^3}{6} +$$

$$+ \left\{X_i^{IV}(x).x'^4 + 6X_i'''(x).x'^2x'' + 3X_i(x).x''^2 +\right.$$

$$\left. + 4X_i''(x).x'x''' + X_i'(x).x^{iv}\right\}\frac{dt^4}{24} + \ldots\ldots\ldots\ldots$$

with like expansions for $X_i(x^{(3)})$, ... in parameters s, ... Substituting these series expansions for X_i in the above determinant and subtracting vertical columns in a proper manner, we have

$$\begin{vmatrix} y & y_1x' + \ldots & y_2(x')^2 + \ldots & y_3(x')^3 + \ldots & \ldots & y_{r+1}(x')^{r+1} + \ldots \\ X_1 & X_1'x' + \ldots & X_1''.(x')^2 + \ldots & X_1'''.(x')^3 + \ldots & \ldots & X_1^{r+1}.(x')^{r+1} + \ldots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ X_r & X_r'x' & \cdots & \cdots & \cdots & \cdots \end{vmatrix}$$

Or disregarding x', x'', ... which are invariant, and retaining only the elements of lowest degree in dt, ds, ..., we have

$$\phi_1 \begin{vmatrix} y & y_1 & y_2, & \ldots & y_{r+1} \\ X_1 & X_1' & X_1'', & \ldots & X_1^{r+1} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ X_r & X_r' & X_r'' & \ldots & X_r^{r+1} \end{vmatrix}.$$

Since x is also invariant, $\phi^2 = \frac{d\phi_1}{dx}$, which would be the above determinant with the last column changed to y_{r+2}, X_1^{r+2}, ... X_r^{r+2}.

13. $\boxed{X_1q,\ X_2q,\ \ldots\ldots\ X_{r-1}q,\ yq}$ leaves invariant x and the ratio $\phi_2 : \phi_1$, where ϕ_2, ϕ_1 are determinants defined in 12.

Since x also remains invariant, we may write our differential invariants

$$\Phi_1 = \frac{\phi_2}{\phi_1}.$$

$$\Phi_2 = \frac{d\Phi_1}{dx}.$$

14. The special linear group

$$\boxed{p,\ q,\ xq,\ xp - yq,\ yp}$$

has the point-invariant

$$D = \begin{vmatrix} x & y & 1 \\ x^{(2)} & y^{(2)} & 1 \\ x^{(3)} & y^{(3)} & 1 \end{vmatrix}.$$

Expressing $x^{(2)}$, $y^{(2)}$; $x^{(3)}$, $y^{(3)}$ in series expansion in terms of t, s,

$$D = \begin{vmatrix} x & y & 1 \\ x + x'\,dt + x''\frac{dt^2}{2} + \ldots, & y + y'\,dt + y''\frac{dt^2}{2} + \ldots, & 1 \\ x + x'\,ds + x''\frac{ds^2}{2} + \ldots, & y + y'\,ds + y''\frac{ds^2}{2} - \ldots, & 1 \end{vmatrix}$$

$$= I_1\frac{dt\,ds^2}{2} + I_2\frac{dt\,ds^3}{6} + I_3\frac{dt\,ds^4}{24} - I_4\frac{dt^2\,ds^2}{12} + I_5\frac{dt\,ds^5}{120} +$$

$$+ I_6\frac{dt^2\,ds^4}{48} + \ldots,$$

where

$I_1 = x'\,y'' - x''\,y' = y_2\,(x')^3,$

$I_2 = x'\,y''' - x'''\,y' = y_3\,(x')^4 + 3y_2\,(x')^2\,x'',$

$I_3 = x'\,y^{iv} - x^{iv}\,y' = y_4\,(x')^5 + 6y_3\,(x')^3x'' + 3y_2\,x'\,(x'')^2 + 4y_2\,(x')^2\,x''',$

$I_4 = x'''\,y'' - x''\,y''' = y_2\,[\,(x')^2\,x''' - 3x'\,(x'')^2] - y_3\,(x')^3\,x'',$

$I_5 = x'\,y^{v} - x^{v}\,y' = y_5\,(x')^6 + 10y_4\,(x')^4\,x'' + 15\,(x'\,x'')^2 + 10y_3\,(x')^3\,x''' +$
$+ 10y_2\,x'\,x''\,x''' + 5y_2\,(x')^2\,x^{iv},$

$I_6 = x''\,y^{iv} - x^{iv}\,y'' = y_4\,(x')^4\,x'' + 6y_3\,(x'\,x'')^2 + y_2\,[3\,(x'')^3 + 4x'\,x''\,x''' -$
$- (x')^2\,x^{iv}\,].$

From these six invariant functions we eliminate the differentials x' x'', ... obtaining the differential invariants:

$$\phi_1 = \left\{ 3\, I_1 I_3 - 12\, I_1 I_4 - 5\, I_2^{\,2} \right\} : (I_1)^{\frac{8}{3}} = (3y_2 y_4 - 5y_3^{\,2}) : y_2^{\frac{8}{3}}.$$

$$\phi_2 = \left\{ 15\, I_1^{\,2} I_6 + 3\, I_1^{\,2} I_5 + \tfrac{40}{3} I_2^{\,3} - 15\, I_1 I_2 (I_3 - 2\, I_4) \right\} : I_1^{\,4}$$

$$= \left\{ 3y_2^{\,2} y_5 - 15 y_2 y_3 y_4 + \tfrac{40}{3} y_3^{\,3} \right\} : y_2^{\,4}.$$

15. The general linear group

$$\boxed{p,\ q,\ xq,\ xp - yq,\ yp,\ xp + yq}$$

leaves invariant the quotient

$$Q = \begin{vmatrix} x & y & 1 \\ x^{(2)} & y^{(2)} & 1 \\ x^{(3)} & y^{(3)} & 1 \end{vmatrix} : \begin{vmatrix} x & y & 1 \\ x^{(3)} & y^{(3)} & 1 \\ x^{(4)} & y^{(4)} & 1 \end{vmatrix}.$$

Using t, s, r as parameters of three successive points, we find

$$Q = \begin{vmatrix} x & y & 1 \\ x + x'dt + \ldots & y + y'dt + \ldots & 1 \\ x + x'ds + \ldots & y + y'ds + \ldots & 1 \end{vmatrix} : \begin{vmatrix} x & y & 1 \\ x + x'ds + \ldots & y + y'ds + \ldots & 1 \\ x + x'dr + \ldots & y + y'dr + \ldots & 1 \end{vmatrix}$$

$$= \left\{ \begin{array}{l} k_1 I_1 \,|\, dt\, ds^2 \,| + k_2 I_2 \,|\, dt\, ds^3 \,| + k_3 I_3 \,|\, dt\, ds^4 \,| + k_4 I_4 \,|\, dt^3 ds^2 \,| + \\ + k_5 I_5 \,|\, dt\, ds^5 \,| + k_6 I_6 \,|\, dt^2 ds^4 \,| + k_7 I_7 \,|\, dt\, ds^6 \,| + k_8 I_8 \,|\, dt^2 ds^5 \,| + \\ \qquad + \,|\, k_9 I_9 \,|\, dt^3 ds^4 \,| \end{array} \right\} :$$

$$: \left\{ \text{Similar expression in } ds,\ dr. \right\},$$

where k_i are constants, $|\, dt^a\, ds^b \,| = \begin{vmatrix} dt^a & dt^b \\ ds^a & ds^b \end{vmatrix}$, and I_i are functions defined as in 14. The form of this expansion for Q shows at once the invariance of the quotients $I_2 : I_1$, $I_3 : I_1$, ... Denoting these ratios by R, we have

$$R_2 = I_2 : I_1 = (x'y''' - x'''y') : (x'y'' - x''y'),$$
$$R_3 = I_3 : I_1 = x'y^{iv} - x^{iv}y') : I_1,$$
$$R_4 = I_4 : I_1 = (x'''y'' - x''y''') : I_1,$$
$$R_5 = I_5 : I_1 = (x'y^{v} - x^{v}y') : I_1,$$
$$R_6 = I_6 : I_1 = (x''y^{iv} - x^{iv}y'') : I_1,$$
$$R_7 = I_7 : I_1 = (x'y^{vi} - x^{vi}y') : I_1,$$
$$R_8 = I_8 : I_1 = (x''y^{v} - x^{v}y'') : I_1,$$
$$R_9 = I_9 : I_1 = (x'''y^{iv} - x^{iv}y''') : I_1.$$

In these eight functions we must express y^i in terms of y_i and x^i, and then eliminate the differentials x', x'', ... This work of elimination is quite tedious, but may be briefly indicated. We construct three functions.

$$A \equiv 3R_3 - 12R_4 - 5R_2^2 = \frac{3y_2y_4 - 5y_3^2}{y_2^2}(x')^2,$$

$$B \equiv 15R_6 + 3R_5 + \frac{40}{3}R_2^3 - 15R_2R_3 + 30R_2R_4$$

$$\equiv \frac{3y_2^2y_5 - 15y_2y_3y_4 + \frac{40}{3}y_3^3}{y_2^3}(x')^3,$$

$$C \equiv 18R_8 + 3R_4 - 60R_9 - 21R_2R_5 - \frac{35}{3}R_2^4 + 35R_2^2R_3 + 70R_2^2R_4 + 210R_4^2$$

$$\equiv \frac{3y_2^3y_6 - 21y_2^2y_3y_5 + 35y_2y_3^2y_4 - \frac{35}{3}y_3^4}{y_2^4}(x')^4,$$

and eliminate from these x', giving the differential invariants

$$\Phi_1 = (3y_2^2y_5 - 15y_2y_3y_4 + \tfrac{40}{3}y_3^3) : (3y_2y_4 - 5y_3^2)^{\frac{3}{2}}$$

$$\Phi_2 = (3y_2^3y_6 - 21y_2^2y_3y_5 + 35y_2y_3^2y_4 - \tfrac{35}{3}y_3^4) : (3y_2y_4 - 5y_3^2)^2.$$

MATHEMATICAL DEFINITIONS. BY MOSES C. STEVENS.

PERFORMANCE OF THE TWENTY-MILLION-GALLON SNOW PUMPING ENGINE OF THE INDIANAPOLIS WATER COMPANY. BY W. F. M. GOSS.

The fact that a pumping engine recently installed within the State of Indiana has given a duty performance higher than that previously reported for any pumping engine in any country is deemed of sufficient moment to merit the attention of the Academy.

This engine was built by the Snow Steam Pump Works of Buffalo, N. Y., and its installation at the Riverside station of the Indianapolis Water Company was completed in season for an acceptance test in July, 1898. It is a triple-expansion, fly-wheel engine, having a single acting pump below and in line with each of the three steam cylinders. Its principal dimensions are as follows:

	Inches.
Diameter of cylinders:	
High pressure	29
Intermediate	52
Low pressure	80

	Inches.
Diameter of piston rods:	
High pressure	6
Intermediate	7
Low pressure	8
Diameter of pump plunger (three single acting)	33
Stroke of all pistons and plungers	60

The more important conditions prevailing during the test of July 5 were substantially those of every-day service, and were as follows:

Revolutions per minute	21.5
Steam pressure	155.6
Total pressure against which pumps were operated (water pressure against which pumps delivered, plus suction lift.) pounds	88.7
Indicated horse power	775.5

Under these general conditions it was found that the engine performed 11,725,000,000 foot-pounds of work at the pump, on a consumption of 79,-093,000 British thermal units, giving a duty per million B. T. U. of 150.1 million foot-pounds, a performance which, as already noted, exceeds by a liberal margin that obtained in any test, the results of which have thus far been published. A comparison of the performance of this engine with that of two other famous engines is as follows:

Name of designer or builder	E. P. Allis Co.	E. D. Leavitt, Jr.	Snow Steam Pump Works.
Locality	Milwaukee, Wis.	Chestnut Hill, Mass	Indianapolis, Ind.
Type	Triple expansion.	Triple expansion.	Triple expansion.
Name of expert conducting test	Prof. R. C. Carpenter	Prof. E. F. Miller.	Prof. W. F. M. Goss.
Capacity—million gals. in 24 hours	18	20.	20.
Indicated horse power, I. H. P.	573.9.	575.7	775.5.
Duty based on 1,000,000 heat units, expressed in million foot-pounds	137	141.9	150.1.

The work incident to the test was advanced by careful, painstaking and conservative methods, and it was believed at the time that the results obtained were as worthy of confidence as those ordinarily derived from such work. In view, however, of the remarkable performance obtained, and to avoid any possible questioning concerning the performance of the engine, the Indianapolis Water Company, with great liberality, arranged for a second test which should be so complete as to admit of a thorough analysis of its action. This second test was run early in the present month (December 3, 1898), and, while all the facts to be derived from it have not yet been determined, enough is known of them to make certain the accuracy of the previous work. The exceptional performance of the engine having, therefore, been carefully established, it is evident that the engine represents a very high standard of engineering practice. It marks the engineering progress of the day. This makes it not only a machine in which its owners may take just pride, but one which lends lustre to the whole State.

Tests to Determine the Efficiency of Locomotive Boiler Coverings.

By W. F. M. Goss.

The extent of heat losses occurring by radiation from a modern locomotive boiler under service conditions has long been a matter of speculation. There have been many investigations to determine the radiation from pipes and other steam heated surfaces, usually within buildings, but until recently no tests have been made which would disclose the effect of the air currents which, at speed, circulate about a locomotive boiler.

During the past summer (1898), however, Mr. Robert Quayle, Superintendent of Motive Power of the Chicago and Northwestern Railroad Company, in co-operation with manufacturers of boiler coverings, and, with the assistance of the undersigned, undertook to determine both the heat losses from a boiler and the relative value of several different makes of boiler coverings designed to reduce such losses. The following is a brief abstract of a report of results submitted to Mr. Quayle:

In carrying out the tests, two locomotives were employed; one to be hereafter referred to as the "experimental locomotive" was subject to the varying conditions of the test; the other being under normal conditions and serving to give motion to the experimental locomotive, and, also, as a source of supply from which steam could be drawn for use in maintaining the experimental boiler at the desired temperature. The experimental locomotive was coupled ahead of the normal engine, and, consequently, was first when running to enter the undisturbed air. The action of the air currents upon it, therefore, was in every way similar to those affecting an engine doing ordinary work at the head of a train.

The boiler of the experimental locomotive was kept under a steam pressure of 150 pounds by a supply of steam drawn from the boiler of the normal engine in the rear. There was no fire in the experimental boiler, which at all times was practically void of water. Precautions were taken which justified the assumption that all water of condensation collecting in the experimental boiler was the result of radiation of heat from its exterior surface. This water of condensation was collected and weighed, thus serving as a means from which to calculate the amount of heat radiated.

The dimensions of the experimental boiler are shown by Table I:

TABLE I.

Dimensions of Boiler.

Diameter, in inches	52
Heating surface (square feet)	1,391
Total area of exterior surface, not including surface of smoke box	358
Area of surface covered (square feet)	219
Area of steam heated exposed surface not covered	139
Ratio of surface covered to total surface	.61

The results of the tests, briefly stated, are shown in Table II:

TABLE II.

Pounds of Steam at 150 Pounds Pressure Condensed per Minute.

Bare boiler at rest	6.8
Bare boiler moving at a uniform speed of 28.3 miles per hour	14.3
Boiler covered in the usual way with approved material—61 per cent. of the total surface only being protected—at rest	3.0
Boiler covered in the usual way with approved material—61 per cent. of the total surface only being protected—moving at a uniform speed of 28.3 miles per hour	5.3

Assuming a rate of steam consumption by engine, and an evaporative efficiency of the boiler which represent results obtained in fair, average practice, the heat losses disclosed by the preceding figures may be transformed into power losses, which are as follows:

TABLE III.

Horse-Power Equivalent of Heat Radiated from Boiler.

Bare boiler, locomotive at rest	12
Bare boiler, locomotive running 28.3 miles per hour	25
Boiler covered with approved material in a manner common to good practice, locomotive at rest	4.5
Boiler covered with approved material in a manner common to good practice, locomotive running 28.3 miles per hour	9.3

Again, the results obtained afford a basis from which calculations may be made to show the extent of losses which will occur when the locomotive is run at higher speeds and under lower atmospheric temperatures. For example, it can be shown that had the boiler tested been run at a speed of eighty miles an hour under a steam pressure of 200 pounds, when the atmospheric temperature is 0 degrees, it would, if bare, have radiated an amount of heat which is the equivalent of sixty-seven horse power, and if covered in the most approved manner it would have radiated an amount of heat which is the equivalent of twenty-five horse power.

It will be seen that the radiation losses are quite sufficient to merit the earnest attention of those interested in improving the performance of locomotives.

The Leonids of 1898. By John A. Miller.

As the results of the observations of the Leonid shower of 1898, made at various places in the United States, are accessible, this note shall only have to do with the observations made at Bloomington, Indiana.

We limited ourselves chiefly to two classes of observations. First, the determination of the number of Leonids that fell during certain periods of time between November 12 and November 19. We hoped from this data to determine the density and the width of the stream at this point in its path. We had prepared a circular map of the sky with a radius of about 32° and a center near γ Leonis, and confined our watch to this portion of the heavens. The following table exhibits the results of these observations. It should be added, however, that these observers were making their first meteor observations and that their judgment as to whether a given meteor was a Leonid or non-Leonid was probably in many instances prejudiced in favor of the former. Hence I am inclined to believe that about eighty per cent. of the meteors observed were Leonids; the remainder belonged to other streams.

Date.	Period Begins.	Period Ends.	Number of Meteors.	Condition of Sky.	Remarks.
November 12.	4.00 a.m.	4.30 a.m.	15	Cloudless	No distinction as to class of meteors
November 12..	4.30 a.m.	5.00 a.m.	21	Cloudless	No distinction as to class of meteors
November 12..	11.00 p.m.	12.00 m.	......	Cloudy	
November 13..	11.00 p.m.	12 00 m.	......	Cloudy	
November 14..	12.01 a.m.	4.00 a.m.	......	Cloudy	Not a break in the sky.
November 14..	4.00 a.m.	5.00 a.m.	2	Cloudy	Only a small patch of sky visible.
November 14..	11.00 p.m.	12.00 p.m.	41	Cloudless	
November 15..	12.11 a.m.	12.30 a.m.	20	Cloudless	
November 15..	12.30 a.m.	12.45 a.m.	18	Cloudless	
November 15..	12.45 a.m.	1.00 a.m.	14	Cloudless	
November 15.	1.00 a.m.	1.15 a.m.	14	Cloudless	
November 15..	1.15 a.m.	1.30 a.m.	22	Cloudless	
November 15..	1.30 a.m.	1.45 a.m.	22	Cloudless	
November 15..	2.00 a.m.	2.15 a.m.	20	Cloudless	
November 15..	2.50 a.m.	3.05 a.m.	27	Cloudless	
November 15..	4.10 a.m.	4.30 a.m.	28	Cloudless	Of these, 25 were certainly Leonids.
November 15..	10.30 p.m.	11.20 p.m.	None	Cloudless	
Nov. 15-16.....	11.50 p.m.	12.25 a.m.	1	Cloudless	This was a Leonid.
November 16..	4.30 a.m.	5.00 a.m.	6	Cloudless	These were Leonids.
November 19..	1.00 a.m.	1.30 a.m.	1	Cloudless	This was a Leonid. It was as bright as Regulus.

On November 15, at 3:02 a. m., a green point of light appeared in the sickle at about right ascension 10h and declination 22°. Gradually the point of light seemed to spread until it covered an area. In a few seconds this area faded slowly and disappeared. It was the only stationary meteor that we observed.

Many meteors were observed that appeared outside the region covered by the map. These are not included in the foregoing table. For example: I watched the region surrounding Orion (not in the map) from 1:45 to 2:00 a. m., November 15. Fifteen bright Leonids were observed.

The meteors were rarely as bright as the first magnitude stars. The longest trail that we saw was about 110° long, but the average length was not more than 20°. The accompanying figure is that of a normal Leonid as I saw them.

The head of the brightest meteors seemed globular, and to be slightly separated from the tail as if it were surrounded by an envelope of non-luminous gas. The globular appearance was doubtless due to irradiation. The color of the head was generally yellowish red, a little more yellow than Mars, suggestive of a heated iron passing from a white-hot to a red-hot temperature. The tail or train was blue or green. The brighter the tail the greener it appeared. It seemed to me, also, that the brighter trains had a bright, narrow, perfectly straight streak or spine, exactly in the middle of the tail, and in the path described by the head. That whatever cause produced the tail was more intense in the broad part, is shown by the fact that the broad part faded out last, and in case of a very bright meteor some seconds after the head had disappeared.

Our second object was to obtain a permanent record of the paths described by the meteors, and to determine the radiant. To this end we platted the paths on the maps as the meteors fell. In all about 225 paths were platted on four different maps. The paths were then produced. Many of them intersected in a comparatively small area. The average of four determinations for the radiant gave Right ascension=9h, 45m; Declination=21°, 40m.

The number of Leonids that fell during the last shower was not so large as anticipated. This augurs well for a large shower November 13-16, 1899. The observations also show that the stream is wider than formerly supposed.

A Linear Relation Between Certain of Klein's X Functions and Sigma Functions of Lower Division Value. By John A. Miller.

Professor Felix Klein has defined a system of interesting functions by the following equation*:

$$X_{\frac{a}{m}}(u) = C_a \prod_{\mu=0}^{m-1} \sigma_{\frac{a}{m}+e,\ \frac{\mu+e}{m}}(u \mid \omega_1, \omega_2) \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where $\varepsilon = 0$, or $\frac{1}{2}$, according as m is odd or even, and

$$\sigma_{\frac{\lambda}{m}, \frac{\mu}{m}}(u \mid \omega_1, \omega_2 = e^{\left\{\frac{\lambda\eta_1 + \mu\eta_2}{m}\right\}\left\{\frac{u - \lambda\omega_1 + \mu\omega_2}{2m}\right\}} \sigma\left(u - \frac{\lambda\omega_1 + \mu\omega_2}{m} \mid \omega_1, \omega_2\right) \ldots(2)$$

u is the fundamental variable of the elliptic functions, ω_1, ω_2 the periods of an elliptic integral of the first kind, η_1, η_2 the periods of an elliptic integral of the second kind, C_a, a quantity independent of u and $\sigma(u \mid \omega_1, \omega_2)$ is the ordinary Weierstrassian σ-function and where λ, μ and m are integers.

I shall now prove that in the case m is a square number, *i. e.*, $m = n^2$ that $X_{\frac{a}{n^2}}(u)$ *can be expressed as a linear homogeneous function of* $\sigma_{\frac{\lambda}{n}, \frac{\mu}{n}}(nu \mid \omega_1, \omega_2)$.

To do this, we need the so-called *Hermite Law*† which, when specialized to meet our needs, is as follows:

Suppose we are given n quantities defined as follows:

$$x_i = C_i \prod_{j=1}^{n} \sigma(u - a_{i,\ j}) \qquad (i = 1 \ldots n)$$

such that the sum of the zero points in the period parallelogram of the μ-plane is,

$$S = \Sigma a_{i,\ j} = 0,$$

And, suppose that we are given a σ-product,

$$P = f(\omega)e^{(\lambda n_1 + un_2)\left(u + \frac{\lambda\omega_1 + u\omega_2}{2}\right)} \prod_{i=1}^{n} (u - u_i)$$

Such that the sum of the vanishing points of P in the period parallelogram of the u-plane is

$$\sum_{i=1}^{n} u_i = \lambda\omega_1 + \mu\omega_2$$

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* See Felix Klein: "Vorlesungen über die Theorie der Elliptischen Modulfunctionen," Zweiter Band, p. 261, equation 1.

†F. Klein, Elliptische Normal-Curven und Modeln nter Stufe, p. 355, or Crelle's Journal, Band XXXII, Hermites, Lettre à Mr. Jacobi.

Then P can be expressed as a linear homogeneous function of x_i.

Proof:

$$*\sigma(nu \mid \omega_1; \omega_2) = f(\omega_1, \omega_2)\, \Pi\, \sigma\left(u - \frac{m_1\omega_1 + m_2\omega_2}{n} \mid \omega_1, \omega_2\right) \cdot$$

$$e^{\left(\frac{\eta_1 + \eta_2}{2}\right) n(n-1)u} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$m_1, m_2 = 0 \ldots n-1$$

$$\sigma_{\frac{\lambda}{n},\frac{\mu}{n}}(nu, \mid \omega_1, \omega_2) = e^{\left(\frac{\lambda n_1 + \mu n_2}{n}\right)\left(nu - \frac{\lambda\omega_1 + \mu\omega_2}{2n}\right)} \sigma\left(nu - \frac{\lambda\omega_1 + \mu\omega_2}{n} \mid \omega_1, \omega_2\right)$$

[From (2)

$$\therefore \sigma_{\frac{\lambda}{n},\frac{\mu}{n}}(nu \mid \omega_1, \omega_2) =$$

$$e^{\frac{(\lambda n_1 + \mu n_2)}{n}\left(nu - \frac{\lambda\omega_1 + \mu\omega_2}{2n}\right)} e^{\frac{\eta_1 + \eta_2}{2} \cdot n.(n-1)\left(u - \frac{\lambda\omega_1 + \mu\omega_2}{\eta^2}\right)}$$

$$\cdot f_1(\omega), \omega_2) \prod_{\substack{m_1 \\ m_9}\} = 0}^{n-1} \sigma\left(u - \frac{\lambda\omega_1 + \mu\omega_2}{n^2} - \frac{m_1\omega_1 + m_2\omega_2}{n} \mid \omega_1, \omega_2\right)$$

from equations (2) and (3).

Whence $\sigma_{\frac{\lambda}{n},\frac{\mu}{n}}(nu \mid \omega_1, \omega_2)$ is a σ-product of n^2 factors.

Whose residue sum,

$$S = \lambda\omega_1 + \mu\omega_2 + n\frac{(n-1)}{2}\omega_1 + n\frac{(n-1)}{2}\omega_2\,;$$

moreover there are n^2 different quantities

$$\dagger\sigma_{\frac{\lambda}{n},\frac{\mu}{n}}(nu \mid \omega_1, \omega_2)\cdot$$

If now, m define n^2 quantities

$$xi = C_1, \prod_{j=0}^{n^2-1} \sigma(u - u_2 j) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

$$\text{Such that} \quad \sum_{j=0}^{n_2-1} a_{i,}\, j = 0 \quad (i = 0 \ldots . n^2 - 1)$$

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* Jordan: "Cours d'Analyse," Tome 2, p. 388.

† Klein: "Vorlesungen über die Theorie der Elliptischen Modulfunctionen," Vol. II, p. 26.

then by Hermites Law, each of the n^2 $\sigma_{\frac{\lambda}{n}, \frac{\mu}{n}}(nu \mid \omega_1, \omega_2)$

can be expressed as a linear homogeneous function of xi.

We must now divide our discussion into two cases (a)

$n \equiv 1 \pmod{2}$

$$X_{\frac{a}{n^2}}(u) = f_1(\omega_1, \omega_2) \prod_{\mu=0}^{n^2-1} \sigma_{\frac{a}{n^2}, \frac{\mu}{n^2}}(u \mid \omega_1, \omega_2)$$

$$= f_3(\omega_1, \omega_2)\, e^{a\eta_1 + \left(\frac{n^2-1}{2}\right) \eta_2 \left\{u - (a\omega_1 + \frac{\eta^2 - 1}{2}\omega_2)\right\}}$$

$$\cdot \prod_{\mu=0}^{n^2-1} \sigma(u - \frac{a\omega_1 + \mu\omega_2}{n^2} \mid \omega_1, \omega_2),$$

Whence $X_{\frac{a}{n^2}}(u)$ is a σ-product of n^2 factors whose residual sum

$$S = a\omega_1 + \frac{n^2-1}{2}\omega_2.$$

And hence can be expressed as a linear function of x_i defined in equation (4).

* There are n^2 quantities $X_{\frac{a}{n^2}}(u)$.

We have now shown that we can express the n^2 quantities $X_{\frac{a}{n^2}}(u)$ as linear homogeneous functions of x_i, and also the n^2 quantities $\sigma_{\frac{\lambda}{n}, \frac{\mu}{n}}(nu \mid \omega_1, \omega_2)$ as linear homogeneous functions of x_i, whence we can express $X_{\frac{a}{n^2}}(u)$. as a linear homogeneous function of $\sigma_{\frac{\lambda}{n}, \frac{\mu}{n}}(nu \mid \omega_1, \omega_2)$.

Q. E. D.

(b) $n \equiv 0 \pmod{2}$.

In this case,

$$X_{\frac{a}{n^2}}(u) = f(\omega_1, \omega_2) \prod_{\mu=0}^{n^2-1} \sigma_{\frac{a}{n^2}+\frac{1}{2}, \frac{\mu+\frac{1}{2}}{n^2}}(u \mid \omega_1\omega_2) \qquad \text{(Equation (1))}$$

$$f_1(\omega_1, \omega_2) e^{\left\{n^2\left(\frac{a}{n^2}+\frac{1}{2}\right)\eta_1 + \frac{n^2}{2}.\eta_2\right\}\left\{u - \frac{n^2\left(\frac{a}{n^2}+\frac{1}{2}\right)\omega_1 + \frac{n^2}{2}\omega_2}{2}\right.}$$

---

* Klein: Vorlesungen, etc., Vol. II, p. 264.

$$\cdot \prod_{\mu=0}^{n^2-} \sigma\left(u - \frac{a\,\omega_1 + \mu\,\omega_2}{n_2} \,\middle|\, \omega_1, \omega_2\right)$$

Whence $X_{\frac{a}{n^2}}(u)$ is a σ-product of n^2 factors whose residue sum,

$S = a\,\omega_1 + \frac{n^2 - 1}{2}\,\omega_2$ and hence can be expressed as a linear homogeneous function of x i defined in equation (4)

By repetition of the argument made in case (a) it follows that $X_{\frac{a}{n^2}}(u)$ can be expressed as a linear homogeneous function of $\sigma\left(nu \,|\, \omega_{\frac{\lambda}{u}}, \omega_{\frac{\mu}{n}}\right)$.

Hence our proposition is proved for all integral values of n.

A FORMULA FOR THE DEFLECTION OF CAR BOLSTERS.* BY W. K. HATT.

The body bolster of a car is a beam which carries the weight of the car and its loading and transfers this weight to the center of the truck bolster, which, in turn, transfers the weight to the wheels.

The bolsters are either of trussed form or of beam form. In the latter case they are of I section or else with one flange and web plates.

It is quite important to construct the body bolster so that it may be stiff enough to prevent contact at the side bearings. These side bearings are placed between the truck and body bolster to limit the oscillations of the car. Evidently if the side bearings come into contact the consequent friction will offer additional resistance when the car goes around curves.

The problem is to compute the deflection of a beam of variable depth.

In case of beam bolsters the moment of inertia of the cross section may be taken to be a linear function of the distance of the cross section from the free end of the beam.

Referring to Fig. 1, let AB be one-half of a body bolster and OB the curve into which the half-bolster is bent. Any point of this curve is located with reference to O by its co-ordinates x y; mn is a section of the bolster distant x from O;

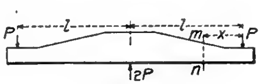

Fig. 4.

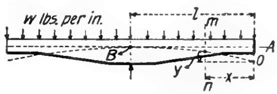

Fig. 1.

*The following is an abstract of a paper which is given in complete form in the Railroad Gazette for December 23, 1898.

l is half the length of the bolster. Let I_0 be the moment of inertia at A, I^1 the moment of inertia at B and I the moment of inertia at the invariable section mn.

Assume the bolster to be uniformly loaded, to be supported at a point and also assume that the moment of inertia I at mn

$$= I_0 - \left\{\frac{I^1 - I_0}{l}\right\} x:$$

that is, the moment of inertia increases directly as x increases.

E is the modulus of elasticity of the material.

Equating the moment of the elastic forces to the moment of the external forces about the neutral axis of section mn, we find

$$+ E I \frac{d^2 y}{d x^2} = - \frac{w x^2}{2}$$

$$\text{or, } E \frac{d^2 y}{d x^2} = - \frac{w}{2} \cdot \frac{x^2}{I} = - \frac{w}{2} \cdot \frac{x^2}{I_0 + \left\{\frac{I^1 - I_0}{l}\right\} x.}$$

Dividing the enumerator of the fraction by the denominator, integrating twice and determining the value of the constants, we find

$$E y = \tfrac{1}{2} \frac{w\ l^4}{I^1 - I_0} \left\{ n \left[\tfrac{1}{2} - C + C^2 \left\{ 1 + \log._e \left(\frac{1 + C}{n + C} \right) \right\} \right] \right.$$

$$\left. + C^3 \log._e \left(\frac{C}{n + C} \right) + \frac{C\ n^2}{2} - \frac{n^3}{6} \right\} \ldots\ldots\ldots\ldots\ldots\ldots (A)$$

$$\text{where } n = \frac{x}{l}, \text{ and } C = \frac{I_0}{(I^1 - I_0)}$$

To obtain the deflection at the side bearing, it would be necessary to substitute for n its proper numerical value along with other values, and compute the resulting value of y. The deflection at the side bearing is not equal this value of y; but is equal to the end deflection minus this value of y.

When n = 1,

$$E y = \frac{w l^4}{2 (I^1 - I_0)} \left\{ \tfrac{1}{3} - \frac{C}{2} + C^2 + C^3 [\log._e I_0 - \log._e I^1] \right\}$$

When n = 1 and $I_0 = 0$,

$E y = \frac{w\ l^4}{6\ I^1}$, and when n = 1 and $I_0 = I^1$ the expression becomes indeterminate

and evaluates to $E y = \frac{w\ l^4}{8\ I^1}$.

The truck bolster may be treated as a cantilever, with a terminal load equal to one-half the center load and a length one-half the length of the bolster as shown in Fig. 4.

If $I = I_0 + \left\{\frac{I^1 - I_0}{l}\right\} x$

then, $E \frac{d^2 y}{d x_2} = -\frac{P x}{I} = -\frac{P x}{I_0 + \left\{ \frac{I^1 - I_0}{l} \right\}}$

Integrating this equation twice and determining the value of the constants, it becomes

$$E y = \frac{P l_3}{I^1 - I_0} \left\{ n \left[1 - C \left(\log._e \left(\frac{1 + C}{n + C} \right) + 1 \right) \right] - C^2 \log._e \frac{C}{C + n} - \frac{n^2}{2} \right\} \quad \text{.......................(B)}$$

$$\text{Where } n = \frac{x}{l} \text{ and } C = \frac{I_0}{I^1 - I_0}.$$

When n =1,

$$E y = \frac{P l^3}{I^1 - I_0} \left\{ \frac{1}{2} - C + C^2 (\log._e I^1 - \log._e I) \right\}.$$

If $I_0 = 0$ and $n = 1$

$$E y = \frac{1}{2} \frac{P l^3}{I^1}$$

When $I^1 = I_0$ and $n = 1$, the expression becomes an indeterminate form which evaluates to $y = \frac{1}{3} \frac{P l^3}{E I_0}$; which is a well-known formula.

Applying formula (A) to a body bolster, uniform load, when $I^1 = 115$, $I_0 = 28$, $l = 53$ in.; n for side bearing $= \frac{23}{53}$, $E = 30{,}000{,}000$, $w = 750$ pounds per running inch, we find that the deflection of side bearing below center = 0.117 inches. This same bolster subjected to actual test showed a deflection at side bearing, under above conditions, of 0.115 inches.

In this case, a close approximation to the deflection at side bearing will be given by the expression

$$d = \frac{1}{15} \frac{w l^4}{E I^1}$$

The method of loading a body bolster for the purpose of a laboratory test used in Purdue University laboratory, may be worth noting.

A wire is stretched between the side bearings, and the bolster is loaded near the ends. The movement of the wire with reference to the center is noted. The bolster is next loaded at points between the ends and the center. Successive loadings are thus applied and the consequent deflections of side bearings noted. Since the deflections are all elastic deflections, the sum of the individual deflections for part loadings may be taken without error to be the total deflection under the sum of the loadings.

Camphoric Acid: Reduction of the Neighboring Xylic Acid.

By W. A. Noyes.

[Abstract.]

An account of the preparation of the neighboring xylic acid has been recently given by the author in the American Chemical Journal. The acid has now been reduced to the corresponding hexahydroxylic acid. The latter boils at 250°—252°, while dihydrociscampholytic acid boils at 244°. The *α*-brom derivative has also been prepared and treated with alcoholic potash. The resulting acid is not ciscampholytic acid. This proves that Collie's formula for camphor cannot be true.

α-Hydroxy-dihydro-ciscampholytic Acid. By W. A. Noyes and J. W. Shepherd.

[Abstract.]

After many ineffectual attempts to prepare the acid by usual methods, it was finally obtained by shaking the ethyl ester of *α*-brom-dihydro-ciscampholytic acid for a long time, at a temperature of 40°—50°, with a strong aqueous solution of barium hydroxide. When the hydroxy acid is warmed with phosphoric acid and lead peroxide (a reaction for *α*-hydroxy acids, recently developed by Baeyer), it gives a ketone which is probably identical with that prepared by Mr. E. B. Harris, under the direction of one of us some years ago. We hope to secure the ketone in larger quantities and that a study of its derivatives will throw new light on the structure of camphor.

Iodine Absorption of Linseed Oil.* By P. N. Evans and J. O. Meyer.

The following statement concerning the necessary excess of iodine and the duration of the reaction, in determining the iodine absorption of oils, occurs in the 1897 edition (German) of Benedikt's "Analysis of Fats and Waxes" (page 152):

*This paper is an abstract of a thesis presented by Mr. J. O. Meyer, for the degree of B. Sc., and placed in the library of Purdue University.

"The [iodine] numbers are quite constant if the iodine solution is present in sufficient excess; the excess, according to Ulzer, when the reaction continues for six hours, must be at least 50 per cent. of the iodine used. Fahrion uses an excess of 100 per cent. of the absorbed iodine (i. e., also 50 per cent. of the iodine used) with a reaction of only two hours, and Holde recommends for this period of reaction the use of 75 per cent. excess of iodine. * * * With a sufficient excess of iodine the results obtained are the same after two hours, six hours, and longer periods."

This refers to the use of the ordinary Hübl's solution of iodine and mercuric chloride, and in the experiments to be described the determinations were carried out in the usual way, varying the two factors—(1) excess of iodine, and (2) duration of reaction.

Excess of Iodine.—It is stated in the passage above quoted that the iodine in excess must be at least 75 to 100 per cent. of the iodine absorbed, and that a larger excess will not affect the results if the reaction is not less than two to six hours in duration.

To test this statement the writers made twenty determinations with a linseed oil, the mixture being allowed to stand six hours, and the excess of iodine ranging from .008 to 3.658 per unit of iodine absorbed. The experiments were made in three series, each series being carried out under as nearly as possible identical conditions, and in spite of two slight discrepancies in the twenty experiments, there was unmistakable evidence that the iodine number steadily and materially increased with the excess of iodine, the increase being nearly as marked between an excess of 1 and of 3.6 as below 1. The iodine numbers obtained varied from 131.2 to 175.3, those with an excess of over 1 from 161.9 to 175.3.

Benedikt gives as minimum and maximum results for commercial linseed oil, according to twenty authorities, 148 and 181, with an average of 170.

Duration of Reaction.—In the above citation from Benedikt, a duration of two hours is said to be sufficient if the excess of iodine is equal to that absorbed (Fahrion), or 0.75 times as great (Holde), while six hours is said to be enough for an excess of 1 according to Ulzer.

The writers carried out eighty experiments to test this point, the excess of iodine varying from .5 to 1.4, and the duration of the reaction from two to eight hours. The eighty experiments were made in six series, and only three of the eighty experiments failed to confirm the conclusion that six hours is not long enough to yield satisfactory results. The iodine numbers obtained ranged from 131 to 184.3.

These results seem to show that the figures given by Benedikt for excess of iodine and duration of reaction are too low, and point to those as preferable which are elsewhere recommended by Schweitzer and Lungwitz, Holde and Dieterich, summed up by A. H. Gill in his "Short-Handbook of Oil Analysis," as follows: "The excess of iodine recommended is from 150 to 250 per cent.; some observers recommend from 400 to 600 per cent. * * * Two hours is sufficient for olive oil, tallow and lard, while for linseed oil, balsams and resins, twenty-four hours should be allowed.

TABLE I.

Showing Effect of Excess of Iodine.

Series No.	Number of Nearly Identical Experiments.	Average Excess of Iodine per 1 Absorbed.	Duration of Reaction.	Average Iodine Number Found.
1	3	.009	6 hours	131.2
	2	.341	6 hours	147.9
	3	.737	6 hours	151.6
2	3	2.888	6 hours	161.9
	3	3.648	6 hours	162.4
3	2	1.503	6 hours	172.3
	2	1.954	6 hours	175.3
	2	3.075	6 hours	173.3

TABLE II.

Showing Effect of Duration of Reaction.

1	3	.589	2 hours	165.0
	3	.566	4 hours	168.0
	3	.540	6 hours	170.7
	3	.526	8 hours	172.3
2	3	.740	2 hours	155.4
	3	.624	3 hours	156.4
	3	.638	4 hours	158.3
	2	.444	6 hours	159.8
	3	.498	8 hours	160.8

TABLE II—CONTINUED.

3	3	.637	2 hours	162.4
	3	.601	4 hours	166.4
	3	.584	6 hours	167.9
	3	.557	8 hours	170.9
4	3	.655	2 hours	175.3
	3	.618	4 hours	179.1
	3	.610	6 hours	182.9
	3	.589	8 hours	184.3
5	3	.951	2 hours	131.9
	3	.940	3 hours	133.4
	3	.951	4 hours	131.0
	3	.896	6 hours	134.4
	3	.889	8 hours	134.6
6	3	1.535	2 hours	165.8
	3	1.495	3 hours	168.2
	3	1.493	4 hours	168.8
	3	1.453	6 hours	170.8
	3	1.396	8 hours	171.5

Some Desmids of Crawfordsville. By Mason B. Thomas.

In looking over the bibliography of Indiana cryptogams we have been greatly surprised at the very meager representation of our Algæ. This we believe to be in some measure due to the lack of correlation of work already done in different parts of the State and upon which no report has been made.

The past spring one of our students, Mr. F. Corey, in working on some Algæ made a list of Desmids that we believe worth while to record. Nothing need be said about the list except that the determinations were carefully made and mounted specimens preserved of each form, together with notes on distribution, etc. It is the intention to prepare as complete a list as possible of Crawfordsville Algæ with a view to some studies on distribution. Permit us to suggest that other records of such work should be presented for the benefit of those working on this group. Personally we should appreciate any such contribution as bearing on some work now in hand.

Closterium lanceolatum, Kg.,
Closterium moniliferum, Ehrb.,
Closterium Leibleinii, Kg., Var. *curtum*, West.

Staurastrum muticum, Berb.
Staurastrum botrophilum, Wolle.

Calocylindrus Thwaitesii, Ralfs.

Penium Berbissonii (Mengh), Ralfs.
Penium margaritaceum, Berb.

Cosmarium pseudobroomei, Wolle.
Cosmarium granatum, Berb.
Cosmarium speciosum, Lund.
Cosmarium Holmiense, Var. *integrum*, Lund.
Cosmarium polymorphum, Nord.
Cosmarium Naegelianum, Berb.
Cosmarium Cordanum, Berb.

Karyokinesis in the Embryo-sac with Special Reference to the Behavior of the Chromatin. By D. M. Mottier.

[Published in Jahrb. für wiss. Botan., Bd. XXX, 1897.]

Nuclear Division in Vegetative Cells. By David M. Mottier.

[Abstract.]

In my paper "Ueber das Verhalten der Kerne bei der Entwickelung des Embryosacks und die Voränge bei der Befruchtung,"[1] I gave a brief account of karyokinesis in the vegetative cells of *Lilium*. My remarks there are confined largely to the behavior of the chromatin, the formation of the spindle being only incidentally referred to. As regards the latter process, however, it is stated that the kinoplasm is present in a much

[1] Jahrbücher für wiss. Bot., Bd. XXXI, 1897.

smaller quantity than in the sexual cells of the same plant. As a rule it is not at first arranged radially about the nucleus, but forms a delicate weft which may be closely applied to the nuclear membrane. Not infrequently a few radiating kinoplasmic fibres are present in addition to the weft. Frequently, and especially in the earlier stages, this weft is so delicate and equally distributed about the nucleus that the most careful staining is necessary to detect its presence, and that for this reason it may be easily overlooked.

In many cases the fibres of this weft are collected in larger and looser masses at different parts on the nuclear membrane, when the weft is more easily demonstrated. The kinoplasmic fibres of the weft form a multipolar spindle which is rapidly transformed into the typical bipolar type. In the cells of the ovule of *Helleborus* the cap-like masses of kinoplasmic fibres upon diametrically opposite sides of the nucleus is often more readily seen than in *Lilium.*

Recent investigations which tend to confirm the above statement, have shown that these accumulations of kinoplasmic fibres are characteristic of a definite phase in the development of the spindle in certain vegetative cells.

The results recently published by Hof[1], which are in accord with the foregoing statement, have contributed much valuable and additional data to our knowledge of the formation of the karyokinetic spindle in higher plants.

Hof finds further that the anlage of the spindle may be bipolar from the beginning, but in *Vicia faba* and *Pteris* sp. along with this type, the monoaxial multipolar anlage occurs.

Thus no fundamental difference exists between the origin of the spindle in vegetative and reproductive cells of the higher plants, save that in the latter (pollen, and embryosac-mother-cells) the anlage of the spindle is multipolar, with little or no definite indication of the future longitudinal axis, while in the former the bipolar anlage may occur side by side with the multipolar mono-axial type. It may be, therefore, as stated by Hof, that "es ergiebt sich, so scheint mir, aus den bisherigen Untersuchungen, dass ein principieller Unterschied zwischen den multipolaren und bipolaren Anlagen der Kernspindel nicht gegeben ist, beide Vorgänge sind durch die monaxial-multipolaren mit einander vereint."

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[1] Hof, A. C.: "Histologische Studien an Vegetationspunkten," Botanisches Centralbl. Bd. LXXVI, 1898.

The development of the karyokinetic spindle as it is now known proves conclusively that centrosomes do not exist in the higher plants.

My own studies, now in progress, confirm my previous statement, and so far as they have extended are not at variance with the results of Hof.

The Centrosome in Dictyola. By David M. Mottier.

[Published in Ber. d. deutsch. Botan. Gesell., Bd. XVI, 1898.]

The Centrosome in Cells of the Gametophyte of Marchantia. By David M. Mottier.

[Abstract.]

While making preparations to demonstrate to a class the archegonium and its development in *Marchantia polymorpha*, my attention was attracted by conspicuous aggregations on opposite sides of certain nuclei in the stalk cells of the receptacle. Closer observation showed that these aggregations were due to the presence of "centrospheres," about which and among whose radiations were collected chloroplasts and finer cytoplasmic granules.

For our knowledge of centrosomes or "centrospheres" in liverworts, we are indebted largely to the recent researches of Farmer.[1]

"When nuclear division is about to take place," says Farmer, in speaking of the germinating spores in *Pellia epiphylla* Nees, "two structures of a minute size appear on the outside of and in contact with the nuclear wall, and from them beautiful radiations extend. These bodies, or centrospheres, are commonly seen to be diametrically opposite to each other in position, for we have not succeeded in demonstrating them in the perfectly resting cells, nor have we been able to ascertain the existence of any definite particle within them which would indicate the presence of a centrosome. It is true that in some instances such a point could be distinguished, but we do not attach much importance to it, since in the great majority of centrospheres it completely eluded recognition."

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[1] Farmer, J. B., and Reeves, Jesse: "On the Occurrence of Centrospheres in Pellia epiphylla Nees." Ann. Bot., VIII, 219-224, 1894.

Farmer, J. B.: "On Spore-Formation and Nuclear Division in the Hepaticae," Ann. Bot., IX, 469-523, 1895.

Recent researches upon certain brown algae *(Dictyota,*[1] *Stypocaulon*[2] and *Fucus*[3]*)* have shown that the centrosome in plants is in all probability something more than a mere point of insertion of the kinoplasmic radiations. In *Dictyota* there seems to be no doubt but the centrosome is a definite body, being here relatively large and rod-shaped, and from which kinoplasmic fibres radiate. In the vegetative cells of *Marchantia* I can not assert with absolute certainty that a definite central body or centrosome exists in all cases, but I believe that such is the case. In some in which the kinoplasmic radiations are densely stained, the dark center seems to be merely the point of union of the radiations, but if the stain be washed out so that the radiations are almost colorless, a well-defined and densely-stained central body is generally to be seen. Since it is now known that the small hyaline space in which the centrosome is sometimes seen to lie, is an artefact, the term centrosphere at present has reference to the centrosome with its radiations, and it is in this sense that the word is here used. By the time the chromosomes are differentiated, and even earlier, the centrospheres lie nearly diametrically opposite each other, and appear to be in all cases attached to the nuclear membrane. The nucleus is now generally elliptical in shape with rather pointed ends at which the centrosomes are situated. As Farmer states, it does seem that the centrospheres exert a pulling strain upon the nucleus, and I have often found that the ends were prolonged into slender beaks terminating in the centrospheres.

I have not as yet been able to obtain a series of stages illustrating the formation of the spindle. The mature spindle consists of delicate bundles or strands of kinoplasmic fibres extending from pole to pole. The fibres stain readily with gentian violet, so that the spindle although often quite small is not an inconspicuous object even when observed by means of dry lenses.

As soon as the chromosomes are regularly arranged in the equatorial plate, the polar radiations become faint and soon disappear. In some cases no polar radiations were visible at this stage.

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[1] Mottier, D. M.: "Das Centrosom bei Dictyota (Vorläufige Mittheilung)." Ber. der deutsch. bot. Gesellsch., XVI, 1898.

[2] Swingle, W. T.: "Zur Kenntniss der Kern- und Zelltheilung bei den Sphacelariaceen." Jahrb. für wiss. Bot., XXX, 1897.

[3] Strasburger, E.: "Kerntheilung und Befruchtung bei Fucus," Jahrb. für wiss. Bot XXX, 1897.

When the daughter chromosomes have arrived at the poles and before any trace of a nuclear membrane is visible, neither centrosome nor polar radiations are to be seen. Sometimes a small, densely-stained body may be seen lying against the nuclear wall, but since these bodies are precisely like others scattered about in the cytoplasm, it would be mere empiricism to speak of them as centrosomes.

The vegetative cells of the gametophyte of *Marchantia* can not be said to be especially favorable for the study of the karyokinetic process. The nuclei are small and the chloroplasts as a rule collect about the centrospheres, thus obscuring many of the finer details.

ENDOSPERM HAUSTORIA IN LILIUM CANDIDUM. BY DAVID M. MOTTIER.

[Abstract.]

So far as the writer is aware, there is as yet no case on record in which it is known that a special provision is made by the endosperm of any of the *Liliaceae* for increasing the absorbing surface in the chalazal region.

During a study upon the fecundation in *Lilium candidum*, it was noticed that cells of the developing endosperm bordering upon the chalazal surface were rendered strikingly conspicuous by their denser contents and the presence of karyokinetic figures, and that the sharp and regular line of demarkation between endosperm and the tissue of the ovule almost disappears at the chalaza. Here the endosperm cells send out short, irregular tubes which penetrate the tissue of the chalaza in a way similar to that in which the cells of the foot of the sporophyte in *Anthoceros* become rooted in the tissue of the gametophyte.

The growth of the developing seed is such that, before the endosperm completely fills the cavity of the embryo-sac, the chalazal region is forced into a lateral position with respect to the longer axis of the seed. The chalazal end of the embryo-sac originally occupied by the antipodal cells persists as a small cavity, which is now filled with a few endosperm cells, projecting into the chalazal tissue. A longitduinal section of the endosperm at this stage in development, coincident with the plane of the funiculus, presents, in the chalazal region, a picture recalling that of a longitudinal section through the foot of the sporophyte of *Anthoceros*.

There seems to be no doubt but this behavior of the endosperm in *Lilium candidum* is a provision for increasing the absorbing surface of that tissue in the region of greater food supply. These cells of the endosperm may, therefore, be known as *endosperm haustoria.*

A similar behavior of the epidermal cells in certain parts of the embryo, such as the cotyledons, serving as special organs of absorption, is well known, and a few striking illustrations of the same are brought together by Haberlandt in his "Physiologische Pflanzenanatomie."

The narrowed end of the embryo-sac, which extends into the chalazal region in certain *Compositae (Senecio)*, is doubtless associated with a like function. In *Senecio*, however, the antipodal cells not only persist but multiply, while in *Lilium candidum* these disappear early, and the space which they formerly occupied is soon filled by endosperm cells.

THE EFFECT OF CENTRIFUGAL FORCE UPON THE CELL. BY DAVID M. MOTTIER.

[Pub. in Annals of Botany, 1899.]

ABSORPTION OF WATER BY DECORTICATED STEMS. BY G. E. RIPLEY.

It is probably known to all students of botany that the sap in a plant rises chiefly through the wood-cells, and not through the cortex-cells. This can be easily demonstrated by securing two similar leafy shoots from a tree or bush. From one, remove all the cortex for about an inch above the cut end, and from the other the wood for about the same distance. Now place the two prepared ends in water, and observe the rate of wilting as shown by the turgescence of the foliage. In a few hours, if transpiration is rapid, the shoot from which the wood has been removed will begin to wilt, and after a time will lose all turgescence, while the decorticated one will appear almost as fresh as at first and will continue so for a considerable time. This proves that the wood-cells and not the cortex-cells supply the water to the shoot.

Last spring, while performing this experiment in the laboratory of vegetable physiology at Purdue University, it was observed that the third unprepared shoot, used as a control on the other two, wilted much sooner than the decorticated one. This observation at once raised the question in what way the removal of the cortex at the cut end of a shoot would delay wilting. In the unprepared shoot used the wood-cells in touch with the water were only those exposed by the cross-section of the stem, but in the decorticated one, besides these, the cells from which the cortex had been removed, were also brought in touch with the water, thereby increasing the number of wood-cells in contact with the water in the decorticated shoot. As it has already been shown that the cortex is a poor conductor of water, we can see that it will prevent the water from reaching the wood-cells beneath, but if removed from the shoot the water is brought in contact with these cells the same as with those exposed at the cut end of the shoot, and as results show, is taken up by them.

The turgescence of a shoot depends upon the amount of water supplied to it in relation to the amount given off by transpiration, and this can be prolonged by providing a greater supply of water, or by decreasing the rate of transpiration. As the latter, however, is dependent upon the condition of the atmosphere, it is beyond our control; but the supply of water is not. Pressure can be used to increase this supply to the cut shoot, and by this guttation can be produced in the vigorous shoot, and turgescence can be restored in the wilted. But this is too inconvenient to be of much practical value in preserving cut shoots in fresh condition. If the supply of water to a cut shoot can be increased by removing the cortex from above the cut end, this will give a very simple method for prolonging turgescence, a method that all may employ who are lovers of cut flowers and delight to preserve them as long as possible.

In the experiment mentioned, as the decorticated did not wilt as soon as the corticated shoot, the former must have received more water than the latter. If the end of a cut shoot that is in water be removed at different intervals so that fresh cells are exposed to the water, the shoot will not wilt as soon as it would if the fresh cells were not exposed. This is due to the fact that as the cells take up the water they act as a filter and stop all foreign matter present in the water, and so in time the cells are choked, and can not take up more water. When the cortex is removed more wood-cells are exposed, and it may be that the water is not taken up any faster by the shoot, but on account of the greater surface of cells exposed they do not choke so soon. But if the cells exposed by the cross-section do not overload the carrying capacity of the shoot, it should take up more water when the cortex is removed.

In order to determine if different shoots would give results similar to those observed in the elder shoot used in the experiment mentioned, a number of experiments were carried out last fall. The data, from all but three of these experiments, were very satisfactory and supported the first result.

The three which were not very satisfactory were with the tomato, gladiolus and one of the maples. They will be mentioned later. In these experiments duplicates were carried out with all but the rose, dahlia and gladiolus; but were not carried out at the same time except for two of the experiments. The stems for the duplicates, while of the same species, were not always taken from the same plant from which the first stems were secured. The condition of the stems used was noted, efforts being made to secure the two as near alike as possible. The number and condition of the leaves were taken, but the amount of foliage present did not appear to have any appreciable effect upon the results. If, however, a large surface of foliage was employed and suitable apparatus used, it would undoubtedly be apparent in the data.

The length that the stems were decorticated was measured for each experiment, and the relation between the length of cortex removed and the time of wilting is shown in the table.

In the first of the experiments performed last fall, stems from a catalpa were used. The tree stood in the open on high, dry, gravelly soil, and was about ten inches in diameter. Two stems each having the same number of leaves were secured. From one the cortex was removed for about 2.8 cm. above the cut end, from which, just before it was put in the water, a fresh cross-section was made so as to expose fresh cells to the water. About 3 mm. were cut off so that there was left about 2.5 cm. of decorticated stem. A fresh cross-section was also made on the corticated before it was put in water. Both stems were put in water at the same time, September 20, at 11 a. m., with the air temperature at 18.5°C. The sky was cloudy and transpiration was slow that day, but by 9 a. m. the next day, with a clear sky and the temperature at 22.5°C., the corticated stem had wilted. The decorticated did not wilt until after five that evening. Six days later catalpa stems were tried again. This time the cortex was removed for only 1 cm. The stems, prepared as before, were placed in water at 7 a. m., temperature 21°C. At 4 p. m. that day, temperature 24.5°C., the corticated had wilted, the decorticated wilting about three hours later.

If we compare the data secured from these two experiments, we find that in the first, with 2.5 cm. of cortex removed, there is a difference of over eight hours in the wilting of the corticated and decorticated stem; and in the second, with only 1 cm. of cortex removed, there is a difference of only about three hours. Now, if we take for granted that the two corticated stems, if under same conditions, would have wilted at about the same time, we have in the decorticated stems for a difference of 1.5 cm. of cortex removed about five hours difference in their wilting.

It is not supposed that this will not vary, nor that stems from other plants will give the same data, for different stems take up water at different rates; but the following, maple, oak, aster cordifolius, wild cherry, Indian mallow, rose, bittersweet, dahlia and chrysanthemum, with which two experiments were tried from all but the rose and dahlia, gave a similar relation between the length of cortex removed and the time of wilting.

With some of the experiments wilting was slow on account of so much moisture being present in the atmosphere, while in others it was rapid, due to the absence of moisture. But in no instance was it evident that the decorticated stem wilted sooner than the corticated one, though with the tomato and gladiolus the time was apparently the same.

Aster cordifolius gave the best results. In the first experiment with it the corticated wilted in about forty-five hours; the decorticated, with 1 cm. of cortex removed, wilted in about sixty-four hours. In the duplicate, the corticated wilted in about fifty-six hours; the decorticated, with 2 cm. of cortex removed, wilted in about ninety hours. It was cloudy all the time that these two experiments were being carried on, and part of the time was raining, so that transpiration was slow.

If we compare these two experiments we find that in the first there is nineteen hours' difference in the wilting of corticated stem, and decorticated with 1 cm. of cortex removed, and in the duplicate there is thirty-four hours' difference in the wilting of corticated stem and decorticated with 2 cm. of cortex removed. The data secured from the other experiments, except those mentioned as giving no results, were not so marked as the aster. The data from the rose were furnished by Dr. Arthur. Only one experiment was tried but the result was good, the decorticated being almost as fresh as at first, when the corticated had wilted.

It must be remembered that the results given are only approximate, as the eye had to decide when the stems had wilted. With the use of suitable apparatus we might discover a relation between the time of wilting and the length of cortex removed. This, if proven, though it might not be of much value in itself, may bring us a step nearer to the final answer of that great question, How does sap rise in plants?

In the experiments with tomato, gladiolus and one of the maples, no definite results were secured. The tomato stems were very tender and transpiration was so rapid that the stems would wilt in a short time, remain wilted until sundown and then revive only to wilt the next morning. The gladiolus specimens used were secured from a bouquet and were not in a fresh condition, which might account for failure to give results. One of the three maple experiments also gave no difference in time of wilting, but in the evening the decorticated stem revived, while the corticated did not, proving that the former took up water more readily than the latter.

The following table gives the results of the experiments, the average temperature, length of cortex removed, time of wilting of corticated and decorticated, and the difference in time of wilting:

Stems Used.	Length of Stem Decorticated in cm.	Average Temperature in C.	Hours Before Wilting.		Difference in Favor of Decorticated
			Corticated.	Decorticated	
Catalpa	2.5	20.5	22	30+	8+
Duplicate	1.0	22.7	9+	12+	3+
Maple	3.0	21.2	10	36	26
Duplicate	1.5	26.0	20	27.5	7.5
Oak	1.5	29.0	9	13	4
Duplicate	2.0	30.0	7	13.5	6.5
Aster C	1.0	20.2	45	64	19
Duplicate	2.0	18.9	56	90	34
Wild Cherry	1.5	20.1	15	22	7
Duplicate	2.5	22.0	12+	22	10
Indian Mallow	2.0	24.0	7	11	4
Duplicate	1.0	26.7	8	10	2
Rose	3 (about)	....	40	Still fresh.	....
Bittersweet	2.5	19.0	30	37	7
Duplicate	2.5	21.0	36	41	5
Dahlia	2.0	23.0	30	48	18
Chrysanthemum	3.0	26.5	29	46	17
Duplicate	1.5	24.0	33	39	6

Just in what way the removal of cortex delays wilting in the cut shoot is yet to be determined, but that it does is evident from results secured. It seems reasonable to suppose that if the cortex is removed and more wood-cells exposed, the shoots should take up more water, provided the cells exposed by the cross-section are not able to supply all the stem can carry. If they can, however, then the delay in wilting must depend on the fact that the more wood-cells exposed, the more time required for them to choke and break down; and this leaves us with the problem as regards the "absorption of water by decorticated stems," either the supply is greater or the cells do not choke so soon.

Indiana Plant Rusts, Listed in Accordance with Latest Nomenclature.

By J. C. Arthur.

Stability in nomenclature is conceded by all to be important. In botany there should be one recorded name for each plant by which it can be identified, and none other should be valid. If this could be strictly maintained, the study of plants would be simplified, for not only would doubt be removed regarding the true application of a name, but when a name was once learned it would hold good for all time. How different the present status of botanical usage is has been brought to the attention of every one using the successive editions of Gray's Manual, a work that probably has introduced more American students of recent years to an acquaintance with the plants of field and highway than all others combined. Those of us who were brought up botanically on the fifth edition learned to call the pretty little white rue-anemone, so abundant in spring, *Thalictrum anemonoides*, but with the new edition in 1890 we were asked to forget that name—no, not to forget it, but to remember that it is not the right one—and to say, instead, *Anemonella thalictroides*. If one had but to relearn a few hundred names, and feel assured that no further demands would be thrust upon him, the task would seem less wearisome. But the new manual names are scarcely fixed in mind before the valuable work by Britton and Brown comes to us, a work so admirably conceived and executed, and so conveniently devised to assist the learner, that it must be recognized as the foremost manual of our flora, and we are again asked to put away the former names of our little rue-anemone and to rechristen it among our list of acquaintances as *Syndesmon thalictroides*. There are many such instances; for example, the Canada thistle is changed from *Cirsium arvensis* to *Cnicus arvense,* and again to *Carduus arvensis.* If we should include the earlier editions of Gray's Manual, and also the works of other authors, the number of synonyms would be greatly increased, some plants, in fact, having as many as a score of Latin names. If we add to this the not infrequent application of the same name to two or more distinct kinds, the confusion becomes appalling.

All this unfortunate state of affairs in the botanical camp has been recognized for a long time, and various measures have been proposed from time to time, and more or less effectively applied, to bring about a reform. Of these efforts the most prominent are the DeCandolle principles of 1813, the Paris code of 1867, the ruling of the Genoa Congress of 1892, and the Rochester-Madison code of 1892-3. All the clearly defined measures are essentially in accord in recognizing as fundamental the statement made by DeCandolle (1813) in his Elements of Botany (p. 228), viz.: "In order that a nomenclature become universal it must be fixed, and the fixity of that of natural history is founded on this principle, that the first one who discovers an object, or who records it in the catalogue of science, has the right to give it a name, and that this name must be necessarily accepted, unless it already belongs to another object or transgresses the essential rules of nomenclature." The application of this principle of recognizing the first name applied to a plant as its only legitimate and correct name is known as the law of priority. But to disentangle the confusion of a hundred and fifty years or more since Linnæus established binomial nomenclature is a great task, and to promulgate unequivocal rules for the present and future naming of plants is almost equally difficult.

The first bomb that was fired so effectively that the botanical camp was stirred to its center and forced to become aggressive, may be said to be the publication in 1891 of Otto Kuntze's *Revisio generum plantarum.* This work discarded names in general use by the hundreds, almost by thousands, and substituted unfamiliar ones, on the ground of rigid priority. It was like an earthquake shaking the whole structure of the nomenclatorial palace, and threatening no end of disaster. But those who believe that the sooner the inevitable change from a policy of inaction to a fearless reconstruction is made have welcomed the efforts of Dr. Kuntze, and have set about to see in how far he is right and to aid as much as possible in establishing nomenclature upon a firm basis.

The class of plants to which I wish to call attention in this connection, the fungi, was not included in Dr. Kuntze's publication of 1891; but in a recent supplemental volume he has taken it up; and it is because some startling changes are proposed among the genera of rusts, a group of plants with which I have lately been working, that it occurred to me that the members of this Academy might be interested in seeing how the list of plant rusts (*Uredineæ*), which have been published from time to time in its Proceedings since 1893, would look when revised in accordance with what appears to be a rigid application of the law of priority. The time at my disposal has not permitted a thorough re-examination of the nomenclatorial history of every species of the list, yet such work as has been done appears to necessitate some changes, which in part were not contemplated by Dr. Kuntze. Some of these changes have been required in order to make the list conform to the Rochester-Madison code, especially in recognizing 1753 as the limit for priority, instead of 1737, as advocated by Dr. Kuntze, and in permitting specific names of any number of syllables, instead of limiting them to eight syllables. It has also been necessary to revive the genus name *Aregma*, established by Fries (*Obs. Myc.*, p. 225) in 1815, to replace the more familiar name of *Phragmidium*, published by Link in 1816.

The plant rusts of our region fall into two principal groups—the *Melampsoraceæ* and the *Pucciniaceæ*. The four genera of the first group are not affected by Dr. Kuntze's researches, but three of the seven genera of the second group are altered, and these are much the largest genera of all the *Uredineæ*. They are *Puccinia*, which is changed to *Dicæoma; Uromyces*, changed to *Cæomurus* and *Gymnosporangium*, which unfortunately is to be known as *Puccinia*. By these changes sixty-nine species of rusts belonging to the Indiana flora, out of a total of eighty species native to the State, are provided with unfamiliar names.

Puccinia first appears as a genus, subsequent to the priority limit of 1753, in a work published by Adanson in 1763, being adopted from a much earlier work by Micheli, who founded it to receive the common European Juniper rust, now called *Gymnosporangium juniperinum*.* Other authors,

*Since the manuscript of this paper went to the printer the correctness of Dr. Kuntze's interpretation of the generic use of *Puccinia* has been called in question by Professor Magnus, with Dr. Kuntze's subsequent approval. But the criticism does not apply, it seems to me, when 1753 is accepted as the limit of priority, instead of 1737, as held by the German writers.

in particular Willdenow, Gmelin, Schmidel and Persoon, added new species to the genus, and especially such rusts as had teleutospores of a similar shape, whether having one, two or many cells. These additions so overshadowed the original Juniper rust and its allies that the genus came to stand for these more abundant and more characteristic rusts. After a time there were gradually separated the one-celled forms, as *Cæomurus*, almost at once changed to *Uromyces*, the many-celled forms, as *Phragmidium*, and the forms with a gelatinous spore-bed, as *Gymnosporangium*, leaving the common two-celled forms under the old name *Puccinia*. We are now asked to restore the name *Puccinia* to its original use, although its misuse has extended over a full century.

The generic name of *Dicæoma*, which was first distinctively applied to the ordinary two-celled forms, appears to have been introduced by Nees von Esenbeck in 1816 as the name of a section, and was erected into a distinct genus by S. F. Gray in 1821. But it never came into general use, and soon disappeared from current books entirely. Of the rusts usually listed under *Puccinia*, there are forty-seven species in the Indiana flora, which are now to be transferred to *Dicæoma*.

The case of the third genus, *Uromyces*, embracing the one-celled rusts, is simpler but quite as annoying. The genus was named by Link in 1809; but not finding the name to his liking, he rechristened the genus seven years afterward, and now after all these years we are called upon to readopt the earlier name, dropping the name *Uromyces*, and to transfer our species to *Cæomurus*. For it was held by DeCandolle long ago that "an author, who has first established a name, has himself no more right than any one else to change it for the simple reason of impropriety," and recent rulings have held the opinion to be sound.

So it comes about that the names of the four largest genera of rusts must be changed, to make them conform to the law of priority, after having been in use almost from the first, and one of these changes is a transfer, which necessarily will cause some subsequent confusion. There appears but one question yet to be answered. We must know whether a thorough inspection of the literature will substantiate the claim that these are in fact the genuine first names for the genera. Feeling considerable confidence in the present conclusion, I here rewrite the Indiana list of *Uredineæ*, to more clearly call attention to the proposed and doubtless inevitable changes.

In the following list the name of the rust which is considered to be the correct first name is printed in small capitals, and when thought necessary for identification is followed by the name that is in more general use printed in italics. The names of the hosts on which the rust grows are given for each species, conforming to the nomenclature of Britton and Brown's "Illustrated Flora of the Northern States and Canada," with the more familiar name added in parenthesis, when a difference occurs. The references after each host are to the page and year of the Proceedings of the Academy, where additional information can be found. Both genera and species are arranged alphabetically.

The list does not include the unattached forms under the genera *Æcidium* and *Uredo*, of which there are about twenty kinds recorded for Indiana. Careful observation supplemented by cultures must finally decide where these belong. The only additions here made to the previous records for the State consist of a few host plants, which are clearly indicated. The species included by Miss Lillian Snyder in her paper before the present session of the Academy could not of necessity be cited.

MELAMPSORACEÆ.

1. CHRYSOMYXA ALBIDA *Kühn.* (*Coleosporium Rubi E. & H.*)
    On Rubus cuneifolius Pursh. 1893:50.
    On Rubus villosus Ait. 1893:50.

2. COLEOSPORIUM HYDRANGEÆ (*B. & C.*). (*Uredo Hydrangeæ* B. & C.)
    On Hydrangea arborescens L. 1893:56. 1896:218.

3. COLEOSPORIUM IPOMŒÆ (*Schw.*) *Bur.*
    On Ipomœa pandurata (L.) Mey. 1896:171, 218.

4. COLEOSPORIUM SOLIDAGINIS (*Schw.*) *Thuem.*
    On Aster azureus Lindl. 1893:50.
    On Aster cordifolius L. 1893:51.
    On Aster Novæ-Angliæ L. 1893:51.
    On Aster paniculatus Lam. 1893:51.
    On Aster puniceus L. 1893:51.
    On Aster sagittifolius Willd. 1893:51.
    On Aster salicifolius Lam. 1893:51.
    On Aster Shortii Hook. 1893:51.

On Aster Tradescanti L. 1893:51.
On Solidago arguta Ait. 1893:51.
On Solidago cæsia L. 1893:51.
On Solidago Canadensis L. 1893:51.
On Solidago flexicaulis L. (*S. latifolia* L.) 1893:51.
On Solidago patula Muhl. 1893:51.
On Solidago rugosa Mill. 1893:51.
On Solidago serotina Ait. 1893:51.

5. COLEOSPORIUM VERNONIÆ *B. & C.*
On Vernonia fasciculata Michx. 1893:51.
On Vernonia Noveboracensis (L.) Willd. 1893:51.

6. MELAMPSORA POPULINA *(Jacq.) Lev.*
On Populus balsamifera L. 1893:51.
On Populus deltoides Marsh. (*P. monilifera* Ait.) 1893:51. 1896:218.
On Populus grandidentata Michx. 1893:51.
On Populus tremuloides Michx. 1893:51.

7. MELAMPSORA FARINOSA *(Pers.) Schrœt.*
On Salix cordata Muhl. 1893:51.
On Salix discolor Muhl. 1893:51. 1896:218.
On Salix fluviatilis Nutt. (*S. longifolia* Muhl.) 1893:52.
On Salix nigra Marsh. 1893:51.

8. PUCCINIASTRUM AGRIMONIÆ *(DC.) Diet.* (*Cæoma Agrimoniæ* Schw.)
On Agrimonia hirsuta (Muhl.) Bick. (*A. Eupatoria* Am. Auct.) 1893:50. 1896:218.
On Agrimonia parviflora Sol. 1893:50.

PUCCINIACEÆ.

9. AREGMA DISCIFLORA *(Tode) nom. nov.* (*Phragmidium subcorticium* Wint.)
On Rosa Carolina L. 1893:52.
On Rosa humilis Marsh. (*R. lucida* Am. Auct.) 1893:52.
On Rosa setigera Michx. 1893:52.

10. AREGMA FRAGARIÆ *(DC.) nom. nov.*
On Potentilla Canadensis L. 1893:52. 1896:218.

11. AREGMA SPECIOSA *Fr.* (*Phragmidium speciosum* Cke.)
On Rosa Carolina L. 1896:219.
On Rosa humilis Marsh. Tippecanoe Co., 5, 1898 (*Arthur*).

12. Cæomurus Caladii (*Schw.*) *Kuntze.* (*Uromyces Caladii* Farl.)
On Arisæma triphyllum (L.) Torr. 1893 : 56. 1896 : 222.
On Arisæma Dracontium (L.) Schott. 1893 : 56. 1896 : 222.

13. Cæomurus caryophyllinus (*Schr.*) *Kuntze.*
On Dianthus Caryophyllus L. 1893 : 56.

14. Cæomurus Euphorbiæ (*Schw.*) *Kuntze.*
On Euphorbia dentata Michx. 1893 : 57. 1896 : 222.
On Euphorbia nutans Lag. (*E. hypericifolia* Gr.) 1893 : 57. 1896 : 222.

15. Cæomurus gaurinus (*Pk.*) *nom. nov.* (*Uredo gaurina* (Pk.) DeT.)
On Gaura biennis L. 1896 : 222.

16. Cæomurus graminicolus (*Burr.*) *Kuntze.*
On Panicum virgatum L. 1893 : 57.

17. Cæomurus Howei (*Pk.*) *Kuntze.*
On Asclepias incarnata L. 1893 : 57. 1896 : 222.
On Asclepias purpurascens L. 1893 : 57.
On Asclepias Syriaca L. (*A. Cornuti* Dec.) 1893 : 57. 1896 : 222.

18. Cæomurus Hedysari-paniculati (*Schw.*) *nom. nov.*
On Meibomia Canadensis (L.) Kuntze (*Desmodium C.*) 1896 : 222.
On Meibomia canescens (L.) Kuntze (*Desmodium c.*) 1893 : 57.
On Meibomia Dillenii (Darl.) Kuntze (*Desmodium D.*) 1893 : 57. 1896 : 222.
On Meibomia lævigata (Nutt.) Kuntze (*Desmodium l.*) 1893 : 57.
On Meibomia paniculata (L.) Kuntze (*Desmodium p.*) 1893 : 57.
On Meibomia viridiflora (L.) Kuntze (*Desmodium v.*) 1893 : 57.

19. Cæomurus Hyperici-frondosi (*Schw.*) *nom. nov.*
On Hypericum Canadense L. 1893 : 57.
On Hypericum mutilum L. 1893 : 57.
On Triadenum Virginicum (L.) Raf. (*Elodea campanulata* Marsh.) 1893 : 57.

20. Cæomurus Junci (*Schw.*) *Kuntze.*
On Juncus tenuis Willd. 1896 : 222.

21. Cæomurus Lespedezæ-procumbentis (*Schw.*) *nom. nov.*
On Lespedeza frutescens (L.) Brit. (*L. reticulata* Pers.). 1893 : 57.
On Lespedeza procumbens Michx. 1893 : 57.
On Lespedeza repens (L.) Bart. 1896 : 222.

22. Cæomurus perigynius (*Halst.*) *Kuntze.*
On Carex pubescens Willd. 1893 : 57.

23. CÆOMURUS PHASEOLI (*Pers.*) *nom. nov.*
On Strophostyles helvola (L.) Brit. (*Phaseolus diversifolius* Pers.). 1893:56. 1896:172, 222.

24. CÆOMURUS PISI (*Pers.*) *Gray.*
On Vicia Americana Muhl. 1896:222.

25. CÆOMURUS POLYGONI (*Pers.*) *Kuntze.*
On Polygonum aviculare L. 1893:57. 1896:223.
On Polygonum erectum L. 1893:58.

26. CÆOMURUS RUDBECKIÆ (*Arth. & Holw.*) *Kuntze.*
On Rudbeckia laciniata L. 1894:152.

27. CÆOMURUS TEREBINTHI (*DC.*) *Kuntze.*
On Rhus radicans L. (*R. Toxicodendron* Am. Auct.). 1893:58.

28. CÆOMURUS TRIFOLII (*Hedw.*) *Gray.*
On Trifolium hybridum L. 1893:58.
On Trifolium medium L. 1893:58.
On Trifolium pratense L. 1893:58. 1896:223.
On Trifolium repens L. 1893:58.

29. DICÆOMA ANDROPOGI (*Schw.*) *Kuntze* (*Puccinia Andropogi* Schw.).
On Andropogon furcatus Muhl. 1896:219.
On Andropogon scoparius Michx. 1896:219.

30. DICÆOMA ANEMONES (*Pult.*) *nom. nov.* (*Puccinia fusca* Relh.).
On Anemone quinquefolia L. (*A. nemorosa* Mx.). 1894:151.

31. DICÆOMA ANEMONES-VIRGINIANÆ (*Schw.*) *nom. nov.* (*Puccinia solida* Schw.).
On Anemone cylindrica Gr. 1896:219.

32. DICÆOMA ANGUSTATUM (*Pk.*) *Kuntze.*
On Scirpus atrovirens Muhl. 1893:52. 1896:219.
On Scirpus cyperinus (L.) Kunth. 1893:52.

33. DICÆOMA APOCRYPTUM (*E. & Tr.*) *Kuntze.*
On Hystrix Hystrix (L.) Millsp. 1893:52.

34. DICÆOMA ARGENTATUM (*Schultz*) *Kuntze.*
On Impatiens biflora Walt. (*I. fulva* Nutt). 1893:52. 1896:220.

35. DICÆOMA ASPERIFOLII (*Pers.*) *Kuntze* (*Puccinia Rubigo-vera* (DC.) Wint.).
On Avena sativa L. 1893:55.
On Elymus Virginicus L. 1893:55. 1896:221.
On Secale cereale L. 1896:221.

36. Dicæoma asteris (*Duby*) *Kuntze.*
On Aster cordifolius L. 1893:52.
On Aster lateriflorus (L.) Brit. (*A. diffusus* Ait.). 1896:219.
On Aster paniculatus Lam. 1893:52.

37. Dicæoma Bolleyanum (*Sacc.*) *Kuntze.*
On Carex sp. 1893:52. 1896:219.

38. Dicæoma Circææ (*Pers.*) *Kuntze.*
On Circæa Lutetiana L. 1893:53. 1896:219.

39. Dicæoma Convolvuli (*Pers.*) *Kuntze.*
On Convolvulus sepium L. 1893:53. 1896:219.

40. Dicæoma Cyperi (*Arth.*) *Kuntze* (*Puccinia nigrovelata* E. & T. and *P. indusiata* D. & H).
On Cyperus strigosus L. 1893:53, 54. 1894:154, 157. 1896:219, 220.

41. Dicæoma Dayi (*Clint.*) *Kuntze.*
On Steironema ciliatum (L.) Raf. 1893:53.

42. Dicæoma dochmia (*B. & C.*) *Kuntze.*
On Muhlenbergia diffusa Schreb. 1893:53, 55.
On Muhlenbergia sylvatica Torr. 1896:221.

43. Dicæoma Eleocharidis (*Arth.*) *Kuntze.*
On Eleocharis palustris (L.) R. & S. 1893:53. 1896:219.

44. Dicæoma emaculatum (*Schw.*) *Kuntze.*
On Panicum capillare L. 1893:53. 1896:220.

45. Dicæoma epiphyllum (*L.*) *Kuntze* (*Puccinia Poarum* Niels.).
On Poa pratensis L. 1893:57.

46. Dicæoma flosculosorum (*A. & S.*) *Martius.*
On Carduus lanceolatus L. 1893:53.
On Taraxacum Taraxacum (L.) Karst. 1893:53. 1896:219.

47. Dicæoma galiorum (*Lk.*) *nom. nov.*
On Galium Aparine L. 1896:172.
On Galium asprellum Michx. 1893:53.
On Galium concinnum T. & G. 1893:53.
On Galium triflorum Michx. 1893:53.

48. Dicæoma Helianthi (*Schw.*) *Kuntze.*
On Helianthus annuus L. 1893:55.

On Helianthus divaricatus L. 1893:55.
On Helianthus grosse-serratus Mart. 1893:55. 1896:221.
On Helianthus strumosus L. 1893:55.
On Helianthus tracheliifolius Mill. 1893:55.

49. DICÆOMA HELIOPSIDIS (*Schw.*) *Kuntze.*
On Heliopsis scabra Dunal. 1893:54.

50. DICÆOMA KUHNIÆ (*Schw.*) *Kuntze.*
On Kuhnia eupatorioides L. 1893:54. 1896:220.

51. DICÆOMA LATERIPES (*B. & R.*) *Kuntze.*
On Ruellia strepens L. 1893:54. 1896:218.

52. DICÆOMA LOBELIÆ (*Ger.*) *nom. nov.*
On Lobelia syphilitica L. 1893:54. 1896:220.

53. DICÆOMA LUDIBUNDUM (*E. & E.*) *Kuntze.*
On Carex sparganioides Muhl. 1896:220.

54. DICÆOMA MENTHÆ (*Pers.*) *Gray.*
On Blephilia hirsuta (Pursh.) Torr. 1893:54. 1896:220.
On Cunila origanoides (L.) Brit. 1893:54.
On Mentha Canadensis L. 1893:54.
On Monarda fistulosa L. 1893:54. 1896:220.
On Koellia pilosa (Nutt.) Brit. 1893:54.
On Koellia Virginiana (L.) MacM. 1893:54. 1896:220.

55. DICÆOMA OBTECTUM (*Pk.*) *Kuntze.*
On Scirpus lacustris L. 1894:151.

56. DICÆOMA PHYSOSTEGIÆ (*P. & C.*) *Kuntze.*
On Physostegia Virginiana (L.) Benth. 1894:151. 1896:220.

57. DICÆOMA POCULIFORME (*Jacq.*) *Kuntze* (*Puccinia graminis* Pers. and *Æcidium Berberidis* Pers.).
On Agrostis sp. 1893:53.
On Avena sativa L. 1893:53. 1896:220.
On Berberis vulgaris L. 1893:49.
On Dactylis glomerata L. 1896:220, 223.
On Hordeum jubatum L. 1896:220, 224.
On Poa compressa L. 1893:53.
On Poa pratensis L. 1893:53.
On Triticum vulgare L. 1893:54.

58. DICÆOMA PODOPHYLLI (*Schw.*) *Kuntze.*
On Podophyllum peltatum L. 1893:54. 1896:221.

59. DICÆOMA POLYGONI-AMPHIBII (*Pers.*) *nom. nov.**
On Polygonum emersum (Mx.) Brit. (*P. Muhlenbergii* Wats.). 1893:55.
On Polygonum hydropiperoides Michx. Tippecanoe Co., 10, 1898 (*Stuart*).
On Polygonum lapathifolium L. Tippecanoe Co., 10, 1898 (*Arthur*).
On Polygonum Pennsylvanicum L. Tippecanoe Co., 10, 1898 (*Arthur*).
On Polygonum punctatum Ell. (*P. acre* H. B. K.). 1893:55, 57.

60. DICÆOMA POLYGONI-CONVOLVULI (*Hedw.*) *nom. nov.*
On Polygonum Convolvulus L. Tippecanoe Co., 10, 1898 (*Arthur*).
On Polygonum scandens L. 1896:223.

61. DICÆOMA PRENANTHIS (*Pers.*) *Kuntze.*
On Nabalus albus (L.) Hook. 1893:55. 1896:221.

62. DICÆOMA RANUNCULI (*Seym.*) *Kuntze.*
On Ranunculus septentrionalis Poir. 1893:55.

63. DICÆOMA RHAMNI (*Gmel.*) *Kuntze* (*Puccinia coronata* Cda. and *Æcidium Rhamni* Gmel.).
On Avena sativa L. 1896:219.
On Calamagrostis Canadensis (Mx.) Beauv. 1893:53.
On Rhamnus lanceolata Pursh. Tippecanoe Co., 5, 1897 (*Arthur*).

64. DICÆOMA SANICULÆ (*Grev.*) *Kuntze.*
On Sanicula Canadensis L. 1893:55.

65. DICÆOMA SILPHII (*Schw.*) *Kuntze.*
On Silphium sp. 1893:55.

66. DICÆOMA SORGHI (*Schw.*) *Kuntze.*
On Zea Mays L. 1893:54.

67. DICÆOMA TENUE (*Burr.*) *Kuntze.*
On Eupatorium ageratoides L. 1893:55. 1896:221.

68. DICÆOMA THALICTRI (*Chev.*) *Kuntze.*
On Thalictrum dioicum L. 1893:55.

*Teleutospores have been seen only on the first host named. The other four hosts show an abundance of uredospores, but the lack of teleutospores leaves the correctness of the determination somewhat in doubt.

69. DICÆOMA URTICÆ (*Schum.*) *Kuntze** (*Puccinia Caricis* Reb. and *Æcidium Urticæ* Schum.)

On Carex bullata Schk. 1893 : 52.

On Carex Frankii Kunth. (*C. stenolepis* Torr.) 1893 : 55.

On Carex fœnea Willd. 1893 : 52.

On Carex lurida Wahl. 1893 : 52.

On Carex Pennsylvanica Lam. 1896 : 172.

On Carex straminea Willd. 1893 : 52.

On Carex virescens Muhl. 1893 : 52.

On Dulichium arundinaceum (L.) Brit. 1893 : 52.

On Urtica gracilis Ait. Tippecanoe Co., 5, 1897 (*Arthur*).

70. DICÆOMA VERNONIÆ (*Schw.*) *Kuntze.*

On Vernonia fasciculata Michx. 1893 : 55.

71. DICÆOMA VILFÆ (*A. & H.*) *nom. nov.*

On Sporobolus asper (Mx.) Kunth. 1896 : 221.

72. DICÆOMA VIOLÆ (*Schum.*) *Kuntze.*

On Viola obliqua Hill (*V. cucullata* Ait.) 1893 : 56.

On Viola striata Ait. 1893 : 56.

73. DICÆOMA VULPINOIDIS (*D. & H.*) *Kuntze.*

On Carex vulpinoidea Michx. 1893 : 56. 1896 : 221.

74. DICÆOMA WINDSORIÆ (*Schw.*) *Kuntze.*

On Sieglingia seslerioides (Mx.) Scrib. (*Triodia cuprea* Jacq.). 1894 : 154. 1896 : 221.

75. DICÆOMA XANTHII (*Schw.*) *Kuntze.*

On Ambrosia trifida L. 1893 : 56. 1896 : 222.

On Xanthium Canadense Mill. 1893 : 56. 1896 : 222.

On Xanthium strumarium L. 1893 : 56.

76. GYMNOCONIA INTERSTITIALIS (*Schl.*) *Lagh.* (*Puccinia Peckiana* Howe and *Æcidium nitens* Schw.).

On Rubus occidentalis L. 1893 : 54.

On Rubus villosus Ait. 1893 : 54. 1896 : 220.

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*This name is made to cover more than one species, but the different forms can not be separated without more study than it is possible to give at the present time. The form on *Carex Frankii*, which has been erroneously referred to *Puccinia Schroeteriana* P. & M., is especially distinct, and probably an undescribed species. Part of this material, however, is without doubt correctly referred as above.

77. Pileolaria brevipes *B. & Br.*

On Rhus radicans L. (*R. Toxicodendron* Am. Auct.) 1893:58. 1896:223.

78. Puccinia globosum (*Farl.*) *Kuntze* (*Gymnosporangium* Farl. and *Rœstelia lacerata* Fr.).

On Cratægus coccinia L. 1893:56.

On Cratægus Crus-Galli L. 1894:153.

On Cratægus mollis (T. & G.) Scheele (*C. subvillosa* T. & G.). Tippecanoe Co., 7, 1898 (*Arthur*).

On Cratægus punctata Jacq. 1893:56.

On Juniperus Virginiana L. 1893:51.

79. Puccinia Juniperi-Virginianæ (*Schw.*) *nom. nov.* (*Gymnosporangium macropus* Lk. and *Rœstelia pyrata* Thax.).

On Malus coronaria (L.) Mill. (*Pyrus coronaria* L.) 1893:56. 1896:218.

On Malus Malus (L.) Brit. (*Pyrus Malus* L.) Floyd Co., 8, 1890 (*Latta*).

On Pyrus communis L. 1893:56.

On Juniperus Virginiana L. 1893:51. 1896:218.

80. Uropyxis Amorphæ (*Curt.*) *Schroet.*

On Amorpha canescens Pursh. 1893:58.

The Uredineæ of Madison and Noble Counties, with Additional Specimens from Tippecanoe County. By Lillian Snyder.

In preceding papers over a hundred species of *Uredineæ* have been reported from the State. Various counties are represented. The largest collection is reported from Tippecanoe, Montgomery and Putnam, while there are a number of counties from which no report has been made. Among the latter are Noble and Madison.

During my collecting in Madison county I have found nine species. Most of these are abundant. Several rusts on leaves of *Carices* were collected, but, with the exception of one, they are not listed here because the hosts have not been determined. The one species on *Carex* given, is classed as *Puccinia carices*, though somewhat different from typical specimens of that species.

The following is a list of the Madison county *Uredineæ*: Following the name of the host is the collector's name, and the date of collection.

Coleosporium sonchi-arvensis (Per.) Lév.

Common on dry ground. Reported from Montgomery, Johnson and Putnam counties in 1893, and from Tippecanoe county in 1896.

On *Aster sp.* 9, 1898 (Snyder).

Melampsora salicina Lév.

Very abundant. Reported from Montgomery, Johnson and Putnam counties in 1893, and from Tippecanoe county in 1896.

On *Salix sp.* 9, 1898 (Snyder).

Puccinia carices (Schum.) Wint.

Very abundant in places. Grows in marshy ground in creek bottom. Reported from Johnson, Montgomery, Putnam, Fulton and Boone counties in 1893, and from Tippecanoe county in 1896.

On *Carex Frankii.* 9, 1898 (Snyder).

Puccinia asteris Duby.

Found only on one species of *aster.* Reported from Montgomery and Tippecanoe counties in 1893.

On *Aster sp.* 9, 1898 (Snyder).

Uromyces Rudbeckii Arth. and Holw.

Abundant. Grows in low, swampy ground. Reported from Montgomery county in 1894.

On *Rudbeckia laciniata* 10, 1898 (Snyder).

Uromyces junci (Schw.) Tul.

Very common in low, black soil. Reported from Tippecanoe county in 1896.

On *Juncus tenuis* 9, 1898 (Snyder.)

Uromyces euphorbiæ C. P.

Common in open fields and along the streets in town. Reported from Putnam, Johnson and Tippecanoe counties in 1893.

On *Euphorbia hypercifolia*, 9, 1898 (Snyder).

Uromyces Howei Peck.

Common. Reported from Johnson, Montgomery, Putnam, Wabash and Dearborn counties in 1893, and Tippecanoe in 1896.

On *Asclepias cornuti* 9, 1898 (Snyder).

Uromyces trifolii (A. and S.) Wint.

Rare. Found in only a very few places in open fields. Reported from Johnson, Montgomery, Putnam, Tippecanoe and Wabash counties in 1893.

On *Trifolium pratense* 11, 1898 (Snyder.)

Besides the Madison county collection, I have in my herbarium fourteen species of *Uredineæ* collected in Noble county by Mr. A. H. King, of Avilla, Ind. In this collection the host of *Puccinia polygoni-amphibii* is new to the State.

Æcidium geranii D. C.

Reported from Vigo county in 1893, and from Tippecanoe in 1896.

On *Geranium maculatum* 5, 1897 (King).

Æcidium grossulariæ D. C.

Reported from Putnam and Montgomery counties in 1893.

On *Ribes cynosbati* 5, 1897 (King).

Cæoma nitens Schw.

First report from the State.

On *Rubus villosus* 5, 1897 (King).

Melampsora populina Lév.

Reported from Montgomery, Putnam, Johnson, Tippecanoe and Marshall counties in 1893.

On *Populus tremuloides* 10, 1897 (King).

Melampsora salicina Lév.

Reported from Montgomery, Johnson and Putnam counties in 1893 and from Tippecanoe in 1896.

On *Salix sp.* 10, 1897 (King).

Roestilia lacerata (Sow.) Fr.

Reported from Montgomery and Putnam counties in 1893 and from Tippecanoe in 1896.

On *Crataegus subvillosa* 6, 1897 (King).

Puccinia maydis Carr.

Reported from Putnam, Montgomery and Dearborn counties in 1893. Not since reported.

On *Zea Mays* 9, 1897 (King).

Puccinia graminis Pers.

Reported from Putnam, Montgomery, Tippecanoe, Marshall and Johnson counties in 1893.

On *Triticum vulgare* 7, 1897 (King).

Puccinia flosculosorum (A. and S.) Wint.

Reported from Marion, Marshall, Putnam, Johnson, Montgomery and Tippecanoe counties in 1893.

On *Taraxacum dens-leonis* 7, 1897 (King).

Puccinia coronata Corda.

Reported from Tippecanoe county in 1893.

On *Avena sativa* 7, 1897 (King).

Puccinia Polygoni-amphibii Per.

Reported from Johnson and Putnam counties in 1893 on *Polygonium acre*, from Fulton and Wabash counties in 1893 on *Polygonium Muhlenbergii*, and from Tippecanoe in 1896 on *Polygonium erectum*.

On *Polygonium hydropiperiodes* 10, 1897 (King).

Puccinia podophylli Schw.

Reported from Johnson, Monroe, Brown, Owen, Vigo, Putnam, Montgomery, Wabash and Dearborn counties in 1893, and from Tippecanoe in 1896.

On *Podophyllum peltatum* 5, 1897 (King).

Uromyces caladii (Schw.) Farlow.

Reported from Vigo, Brown, Montgomery, Putnam, Monroe and Owen counties in 1893, and from Tippecanoe in 1896.

On *Arisæma triphyllum* 5, 1897 (King).

Uromyces trifolii (A. and S.) Wint.

Reported from Johnson, Montgomery, Putnam, Tippecanoe and Wabash counties in 1893.

On *Trifolium pratense* 10, 1897 (King).

The list of additional species to Tippecanoe county is small, only two new species having been found.

Æcidium Lycopi Gerard.

This species was found in swampy ground, and was quite abundant. The leaves and stems of the plant are covered with the *Æcidium* which eats holes in the leaves and destroys the host to some extent.

On *Lycopus sinuatis* 6, 1898 (Snyder).

Puccinia poarum Niels.

Found abundantly in lawns.

On *Poa pratensis* 5, 1897 (Snyder).

Aspergillus oryzae (Ahlburg) Cohn. By Katherine E. Golden.

A. oryzae is a mould which is of much practical interest by reason of its zymotic activity, since it secretes a diastatic ferment, and also for the claim which has been made that under certain conditions of growth, it is convertible into a yeast, and that, like most yeasts, it can give rise to alcoholic fermentation. It would constitute, in fact, if all claims made for it were true, a good working basis for an entire distillery. It has been used by the Japanese for centuries in one of their important fermentation industries, that of saké brewing, though like many other ferments used in early times, its true nature was not understood.

In the manufacture of saké, rice is steamed and then mixed with some rice which is covered with the mould, or else the rice is sown with the spores. The spores germinate in the moist and warm air, forming a much-branched mycelium which penetrates to all parts of the grains. This mycelium in developing secretes a diastatic ferment, which acts on the starch, first liquefying it, then changing the liquefied starch to sugar. The formation of spores is avoided by adding quantities of fresh grain from time to time, and mixing the fresh grain with that which has been inoculated. The addition of fresh grain is repeated several times, the mass thus formed of grains and mould being given the name "taka koji." The koji is mashed with about three times its volume of fresh steamed rice and four times its volume of water, and then allowed to stand at a temperature between 20° and 30°C. After some days the mash clears, from the saccharification of the starch, and a spontaneous fermentation sets in. This fermentation is due, however, to a different organism from A. oryzae. It is presumably on account of this fermentation that the mould has been erroneously called Japanese yeast. The fermentation goes on for two or three weeks, and at the end of that time the liquid is filtered. The resulting liquor is clear, pale yellow, and contains about thirteen per cent. of alcohol.

The mould has not been well known in this country until recently, though it has been known in Europe, and has received considerable attention from European botanists for about twenty years. In later years very enthusiastic claims have been made in regard to its physiological action, it being claimed that in the growth of the mould, "crystals" of diastase were formed on the filaments, that it was also so active and certain in its action as an alcoholic ferment, that in time it would entirely supersede yeast in the fermentation industries.

HISTORICAL.

The work of the first investigator, Ahlburg, in 1876, was the naming and description of the fungus. He called it Eurotium oryzae, because, as he said, the spores did not form chains, and the mycelium was not bent at angles. He described the sporangium as of a yellow color and possessing radiating spore tubes, and later on, in 1878, called attention to unimportant characteristics of the mycelium, thus indicating that he was uncertain in regard to the systematic importance of the various parts. He gave no illustrations, so that it was difficult to tell what he meant. In consequence of this, and that he named the fungus Eurotium, some of the later botanists interpreted the sporangia to be perithecia, and the radiating spore tubes asci.

Cohn, in 1883, in treating of the mould as an industrial factor in the manufacture of rice wine, speaks of it as A. oryzae, though he gives no morphological characteristics. Büsgen, in 1885, treats of the size and appearance of the mycelium, conidiophores, sterigmata, and conidia, though not very fully, as these were secondary considerations in his work. He also speaks of its resemblance to A. flavescens. Büsgen was the first to give a detailed description of the mould so that it was possible to compare it with other members of the genus. In 1893, Wehmer took up the work with the idea of making a detailed examination of the structure, and while he was thus engaged, Schröter's work in the same line appeared. Wehmer has a very careful, detailed description, and also some excellent drawings, and being a careful, conservative investigator, his work is particularly valuable.

Later workers are Takamine, Juhler, Jörgensen, Hansen, Klöcker, Schiönning, and Sorel. Takamine is a Japanese chemist who introduced the mould into this country for the purpose of its introduction into distilleries and breweries, his idea being to do away with the malting of the grain. This is to be effected by mixing the mould with the crushed grain in order to bring about the diastasic change in the starch by a less clumsy and more economical manner than the malting. He took out a patent in this country on the mould, his patent treating of its diastasic function and its transformation to a yeast. The method was introduced into a distillery and there Juhler obtained the mould, and took it to Denmark for study in Jörgensen's laboratory. Juhler claimed that the mould could be changed under certain conditions to a yeast, and Jörgensen indorsed him, and carried the assertion still farther by claiming that other moulds as well as A. oryzae possessed this property. Sorel got like results to those of Juhler and Jörgensen, but he makes a still further assertion in that he claims to reproduce the mould from the yeast when he sowed the yeast in a "not-quite-pure" condition upon the rice. The "not-quite-pure" condition undoubtedly accounts for his results.

Hansen took the opposite view in disclaiming alcoholic fermentation, and conversion of the mould to a yeast. Klöcker and Schionning, who worked in Hansen's laboratory, agree with Hansen's view of the matter, and this conclusion was arrived at after an extended investigation of the mould, this investigation including a repetition of Juhler, Jörgensen, and Sorel's experiments with original material furnished by Takamine, and also pure material. Wehmer in a second paper also agrees with the non-production of yeast and alcoholic fermentation, and states that there are two organisms that take part in the saké brewing, and that Takamine, Juhler, and Jörgensen did not discover the genetic relationship of the two. This, however, does not state the true condition of the case, for Jörgensen was aware of the two organisms present, and states that there is no genetic relation between the two.*

Other workers upon the mould are Atkinson of Tokio, who treated it from the industrial point of view, as did also Hoffman and Korschelt. Cohn, Büsgen, and Ikuta followed, their work being mainly along the same lines, though each one gave some additional information. The morphological and physiological characteristics were carefully worked out by Kellner and his assistants, Mori and Nagaoka.

There has been a large number of investigations made upon the life history of the fungus and yet there are some points left that are not clearly given, as the peculiarities of form due to varying conditions, and also the failure to take advantage from the industrial point of the power which the mould is said to possess of causing alcoholic fermentation. In an English medical journal the statement is made that the mould is capable of producing a strong and certain alcoholic fermentation, and is much more resistive to foreign organisms than is yeast; that for these reasons it would be much more effective and economical than yeast in the fermentation of bread.

MORPHOLOGICAL.

The material for the following experiments was some of the so-called "original" material, obtained from Takamine. This original material is a portion of koji, which was grown without any special precautions to keep it pure. Pure cultures were made from this material, and were also used.

*Jörgensen, A.; "Micro-organisms and Fermentation," p. 93, 1893.

A. oryzae is a mould of a yellowish green color when seen in the mature stage. The color varies with the age of the plant and also with the medium upon which the plant is grown. Favorable solid media are bran, rice, and wort gelatine. On rice and wort gelatine the young growths are of a light yellow green, the color being due to the numberless conidia formed. As the growth ages, the color changes to dark olive green. On plate cultures the mycelia are usually in colonies, due to the massing and germination of a number of conidia in one spot; as a result, the plate presents a very irregular growth appearance (photograph 1). On bran the color of the young growth is much darker than that of the same age on rice, and in old growths the color is brownish olive to dark brown. In very old growths not a trace of green appears.

The mycelium is a mass of fine, fleecy filaments, very much branched, and containing numerous septa. Wehmer states that the branching and septa were not easily seen, except with high magnification, but I had no difficulty in seeing both features with low powers, as photographs 2, 3 will show. These were taken from gelatine-plate cultures. The magnification is 75 diameters. In young growths the filaments are filled with a finely granular protoplasm, which becomes much vacuolated as growth proceeds (photographs 4, 5). The filaments vary much in diameter even in the same culture, the main filament being large, while the branches taper, sometimes these being extremely fine. In old cultures the filaments become very large, thick and rough-walled (photograph 6). They are always colorless.

The conidiophores can usually be distinguished from the mycelial hyphae as they gradually enlarge to the spherical end. The length varies to such an extent that any figures would not mean anything. The conidiophores are sometimes short branches at right angles to the filaments from which they arise sometimes so long that their connection is somewhat difficult to determine. Büsgen gives the length of the conidiophore as .5 mm., Schröter, 1 mm., while Wehmer merely states that they vary in length. They become much enlarged in old cultures, the walls become very much thickened and roughened (photographs 8, 9).

In young growths the sterigmata are short and regular, and vary from a few in number to sufficient to completely cover the spherical head; but in older growths, especially when submerged, they become septate, sometimes a sterigma developing into a conidiophore, which on its end again develops sterigmata. These peculiarities are found readily in moist chamber developments (photographs 10, 11).

The conidia are spherical and are formed by an abstriction from the ends of the sterigmata. They are colorless and smooth-walled when first formed and when grown submerged, but very soon develop a yellow color, which darkens to a green, and when old, olive and brown. As soon as the conidia developed in the drop in a moist chamber reach the air, the walls thicken irregularly and assume a fine warty appearance. Photograph 7 shows the submerged head, photograph 12, older conidia grown in the air. No pictures could be taken that give an adequate idea of the number of conidia formed in a chain, as in their growth they extend so far beyond the plane of the water drop that it was impossible to focus them. And again they are so lightly held together that any attempt to mount them under a cover-glass causes them to separate.

The formation of conidia is the only method of reproduction known; no perithecia have been observed, though they have been mentioned by the earlier investigators, but this has come about through the erroneous designation of the fungus as a Eurotium.

PHYSIOLOGY.

To determine if the mould were capable of causing alcoholic fermentation, the mould spores were shown in ten per cent. solutions of maltose, dextrose, lactose, and sucrose, also wort, all in fermentation tubes. No gas was generated nor was any alcohol formed. The mould, however, grew much better in dextrose and maltose than in lactose and sucrose. The lactose growth remained meager, but the sucrose was merely slower, finally reaching the same extent of growth as the dextrose and maltose.

To test the action in bread, cultures in wort were made of the mould and also of a yeast which gives a vigorous fermentation. After these had grown for five days, sponges were made in which the yeast and mould were used and equal quantities of the other ingredients. In one set the yeast was used alone, in another the mould alone, while in a third the yeast and mould were used together. The sponges were allowed to ferment, then kneaded into dough, and again fermented, at the end of which time they were baked. The yeast sponge fermented most vigorously, the yeast and mould much slower, while the mould sponge showed but very little change. The yeast and mould together took an hour longer than the yeast alone to reach the same degree of fermentation. The loaves from the yeast were of sweet taste and odor, and even-grained. Those from the mould were soggy and heavy, had a sweet odor, but left a sharp aftertaste. The loaves from the yeast and mould were very like those from the yeast, but also left the sharp aftertaste, though this was not unpleasant. Four persons having no knowledge of the constituents of the loaves, selected the ones made from yeast alone as being the best bread.

In testing the germinative power, cultures were made in wort, wort gelatine, Pasteur solution with the four sugars, lactose, dextrose, maltose, and sucrose from inoculating material that varied in age from very young through different periods to one year and eleven months, and which had been grown upon rice, bran, wort gelatine, wort, and Pasteur solution containing the different sugars. The results show that the germinative power lessened with age, but a more important factor than age was that of the original medium in which the culture had been made. Some of the growths from the wort gelatine plates had entirely lost their germinative power, while others were weakened. Wehmer states that the age of the inoculating material made no difference in germinative power, neither did the medium upon which it had been grown.

For ascospore formation young conidia were sown upon gypsum blocks in the usual way for obtaining yeast spores, and in about a month's time rounded masses of protoplasm, resembling yeast spores, were formed in some of the cells, though no cell-wall could be determined for these spore-like bodies. The same spore-like bodies were formed from the protoplasm in mycelial filaments undergoing the same treatment.

No experiments were made directly to determine the diastatic action, as work upon this has been done quite extensively by chemists.

In conclusion I would state that so far as any experiment would show, there was no indication that A. oryzæ has the power of causing alcoholic fermentation, nor of being transformed through any conditions whatever into a yeast. Neither can it be used effectively in bread-making.

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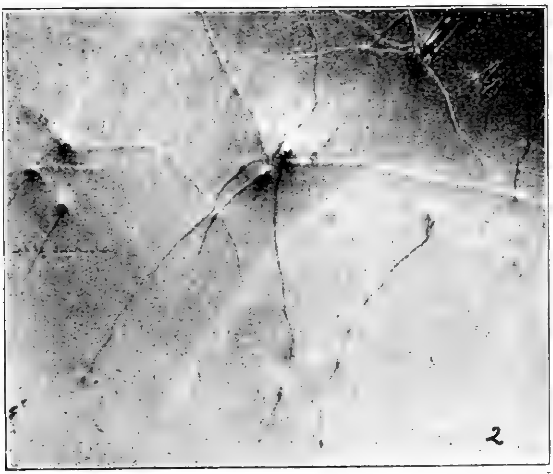
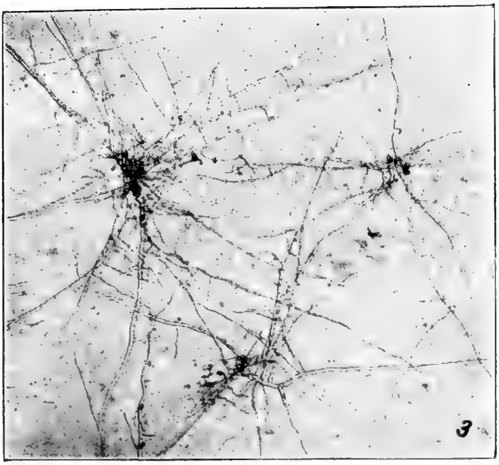
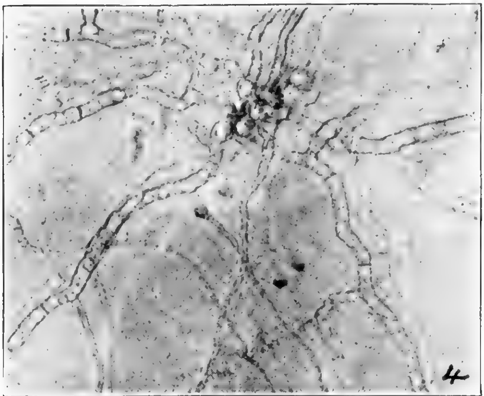
EXPLANATION OF PLATES.

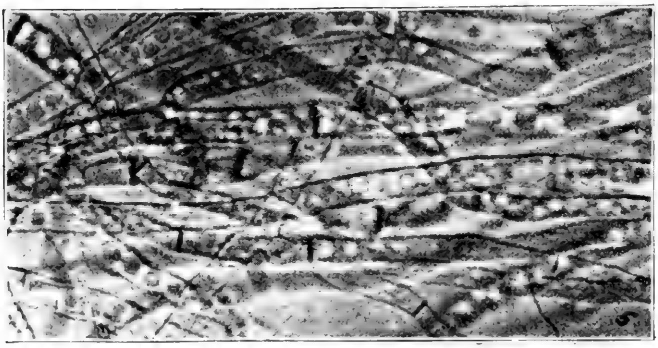
1. Wort gelatine plate culture, about a week old. ×⅔.
2. Germination of conidia in moist chamber. ×75.
3. Germination of conidia in moist chamber, in more advanced stage.
4. Same as 3, but higher magnification. ×495.
5. Filaments from wort gelatine plate culture. ×95.
6. Filaments from wort gelatine plate culture, ten months old. ×495.
7. Conidiophore grown in moist chamber, four days old. ×495.
8. Conidiophore from same source as 6. ×495.
9. Conidiophore from same source as 6. ×495.
10. Moist chamber growth, three weeks old. ×495.
11. Moist chamber growth, three weeks old, showing sterigma developing as conidiophore. ×495.
12. Spores from plate culture, three weeks old. ×495.



Golden on Aspergillus oryzæ.







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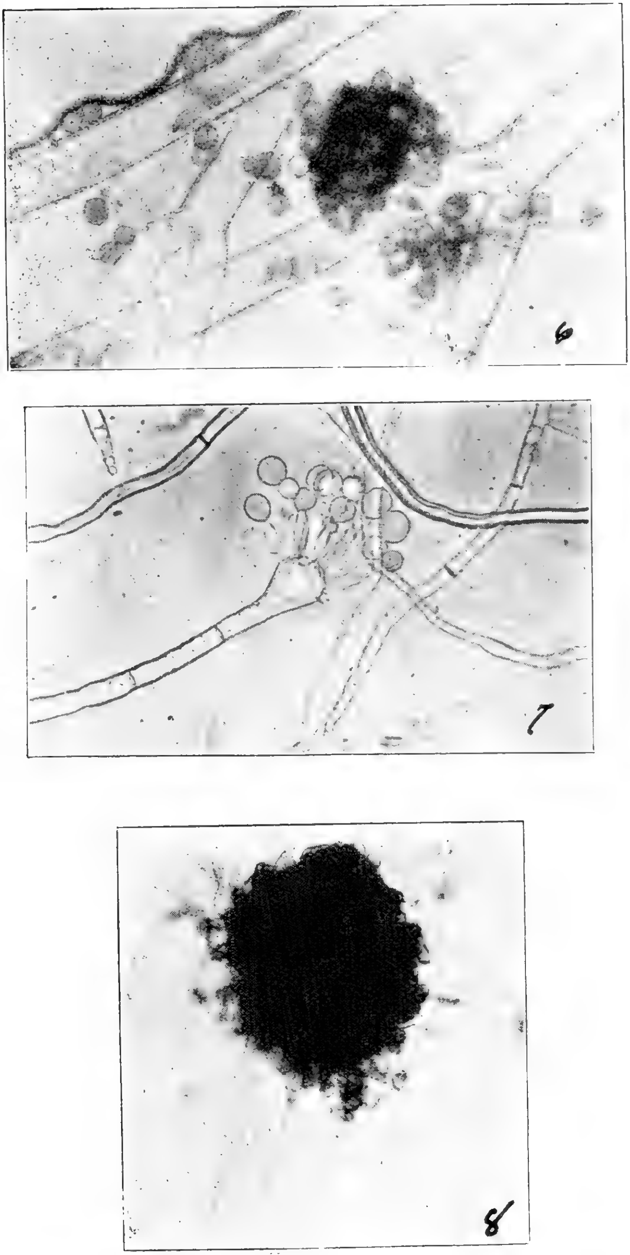

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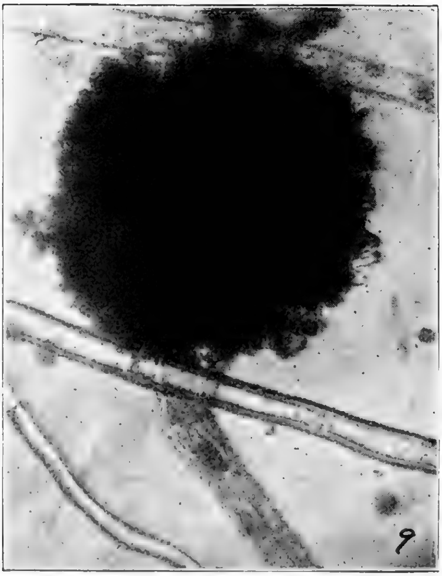

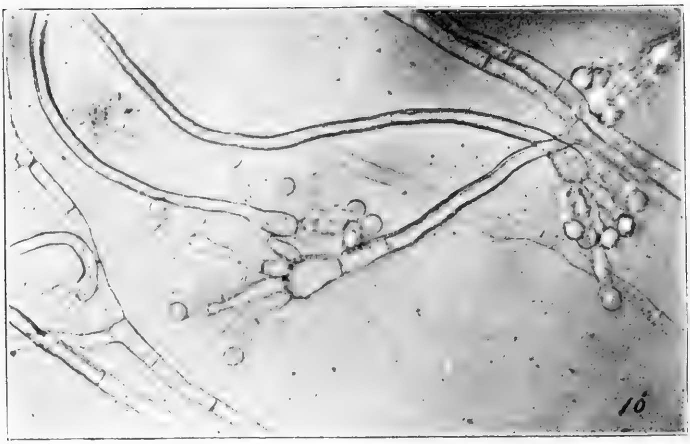

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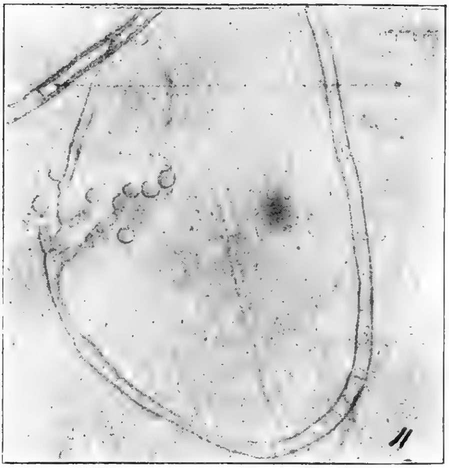

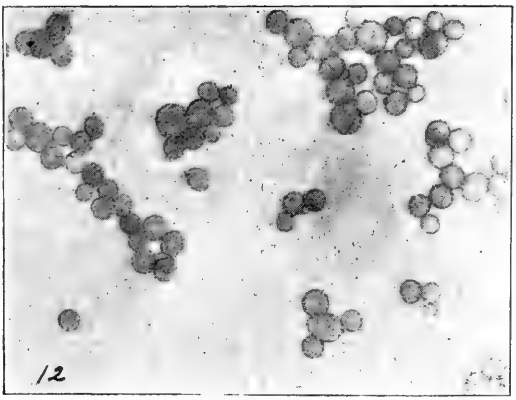

Golden on Aspergillus oryzæ.

A Red Mould. By Ralph Gilson Curtiss.

The mould with which this paper has to deal was first found at Purdue University upon a plate culture which had been exposed to the air. It was at first supposed to be a mixture of a mould with a yeast, and this idea was a natural one in view of the behavior of the form when grown upon gelatine cultures. The characteristics exhibited during growth in this way seem to partake both of those ascribed to moulds and those which we are accustomed to associate with yeast forms. A mycelium is developed first, the early stages of which resemble in their growth those of the common moulds, but which soon disappear completely, its place being taken by a reddish film which covers the entire surface of the culture and which is thickly dotted with red specks. This dotted appearance is what gave rise to the supposition that a yeast was present in company with the mould, and it was only after a series of attenuated cultures had been made from the original plate that the true nature of the growth was ascertained.

It is evident that in a form whose growth shows such a remarkable and abrupt transition from the true mould stage to a yeast-like stage, we have a subject for research which should amply repay the most careful investigation. As soon as it was determined that both appearances were due to the growth of a single mould, cultures were made for the purpose of following its life history.

In fluid cultures the best results have been obtained with wort and Pasteur's solution. On wort kept at room temperature, a growth is apparent in twenty-four hours, and in forty-eight hours colonies are visible throughout the medium as well as covering the surface.

The peculiar red color is noticeable even in the thinnest portion of the growth, that on the surface showing as a pinkish film. This film, when broken by the platinum needle for purposes of examination, is found to possess a considerable toughness and is difficult to remove from the tube, except in large pieces.

A point which will receive more attention in later investigations is that when grown upon sugar solutions, all that portion of the growth which is exposed to the air turns black as it ages, while cultures made at the same time upon wort retain the characteristic red color.

The filaments of this mould vary considerably in size, according to age, the younger ones having the lesser diameter. They are divided at frequent intervals by septa, especially in the older portions; the septa, however, seem in no way connected with the position of the branching hyphæ. The young filaments, which are usually filled with protoplasm that is transparent, sometimes contain a thread of protoplasm which is highly refractive and which shows no vacuoles. It is possible that it is this thread of refractive protoplasm which, in rounding off and becoming denser, produces the small spore-like bodies which are found in the mycelial cells.

The question of the reproductive methods of the red mould has been the chief source of difficulty in its study, and so far as the work has been carried these methods have not been fully determined.

As regards the formation of conidiophores this mould is markedly different from the commoner ones. In spite of the most favorable vegetative conditions having been given, both as to the kind of nutritive solution used in the moist chamber, and as to the temperature, no conidiophores have been discovered. A kind of division into cells, which is perhaps analogous to the formation of conidia in other moulds, takes place (Fig. 1), but observations as to the true significance of the division are not complete. The nearest approach to the formation of conidiophores is in the hypha shown in Fig. 2. Here a rounding takes place in the terminal cell and the hypha back of this rounding is divided by an extraordinary number of septa.

However inadequate the determination of vegetative reproduction, proofs of sexual reproduction have been more abundant. The red specks to which I have referred as being so thickly distributed over the surface of the gelatine cultures occur also in the tube cultures and in the moist chamber. When a culture is examined under the microscope, these specks are seen to be dense, irregularly shaped bodies of extremely varying sizes. (Fig. 3). Some are many times the size of others which have apparently reached the same stage of maturity. They are formed by the interlacing of the filaments and are found completely developed in so short a time that it has been impossible to secure the intermediate stages for photographing. As the interlacing of the filaments goes on, the massing becomes denser at some points than at others, and here these rough, compact, tuberous bodies are found. (Figs. 3, 4, and 5.) Unfortunately their thickness prevents their successful photographing (since it is impossible to focus with the microscope on more than one plane at a time). These bodies conform to a certain extent to the description of sclerotia but their function is evidently not that of a resting body formed under adverse conditions. On the contrary they are formed almost immediately under the most favorable conditions and occur in all cultures. They rather resemble sporocarps in their function, but they do not contain asci, so far as has been determined.

When broken open soon after formation, these bodies are found to contain a large number of small yeast-like cells, which have a cell wall and are filled with protoplasm which is at first clear but soon shows a number (usually two) of denser, spore-like granules. The covering of the body is a rough yellowish wall.

If the yeast-like cells which these bodies contain were seen unaccompanied by any mycelial growth, it would be extremely difficult to distinguish them from the cells of a true yeast. This would appear to give considerable support to the theory that yeast and mould can be developed from the same growth interchangeably, but in reality it does not. Every attempt has been made to secure budding and fermentation from these cells but so far neither has been found. The growth of the cell is in every case by the sending out of a true mycelial filament.

What appears to be another method of producing a body similar to the one I have mentioned is shown in photographs 6 and 7. It may be that one of the filaments seen there fertilizes the other, though at any rate the resulting body is similar in color and appearance to the one formed by the interlacing of the filaments.

Three stages in a peculiar formation are shown in photographs 8, 9 and 10. The process consists in the coiling together in a peculiar manner of two hyphæ which may or may not arise from the same branch of the mycelium. Figures 8 and 9 show the coiling as it begins and figure 10 shows it in a more advanced stage. The body in figure 10 appears to have a definite structure, being formed by the coiling of two hyphæ—whose origin is visible—from the same mycelial branch.

In conclusion it may be stated that the investigations are by no means considered complete, but that it is to be hoped that additions can be made to our knowledge in the near future.

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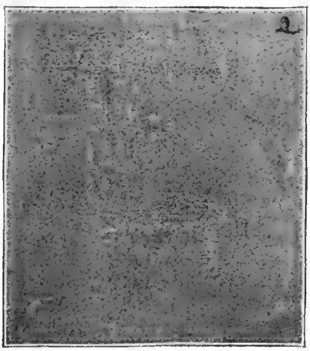
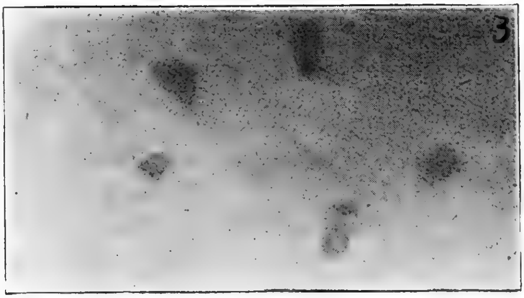
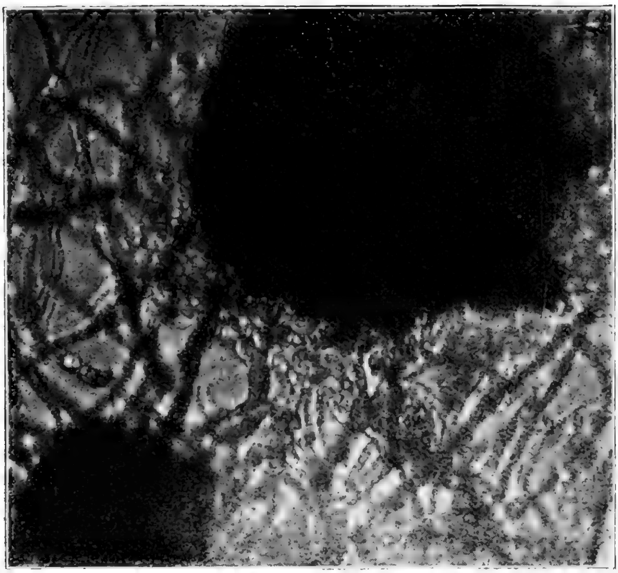
EXPLANATION OF PLATES.

No. 1. Culture on lactose five months old. ×495.
No. 2. Culture in moist chamber on wort three days. ×495.
No. 3. Culture on wort gelatine two days old. ×75.
No. 4. Culture in moist chamber on wort six days. ×495.
No. 5. Culture in moist chamber on wort six days. ×495.
No. 6. Culture in moist chamber on wort seven days. ×495.
No. 7. Culture in moist chamber on wort eight days. ×495.
No. 8. Culture in moist chamber on wort eight days. ×495.
No. 9. Culture in moist chamber on wort eight days. ×495.
No. 10. Culture in moist chamber on wort eight days. ×495.



Curtiss on Red Mould.





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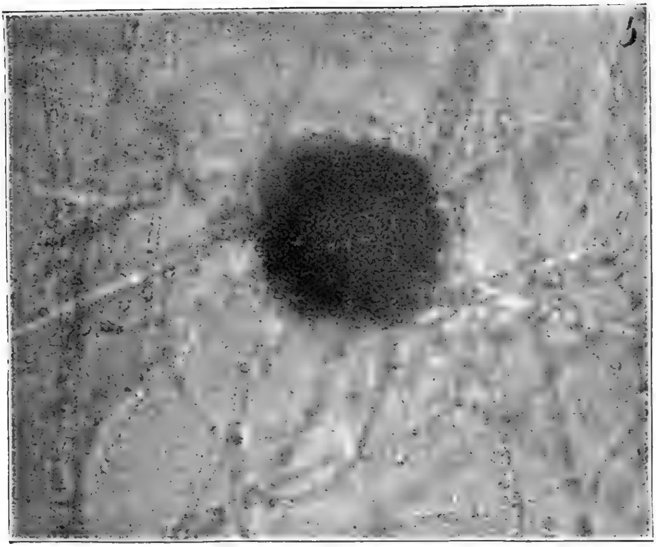

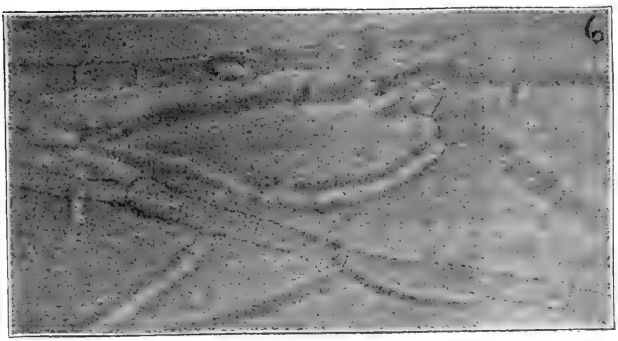

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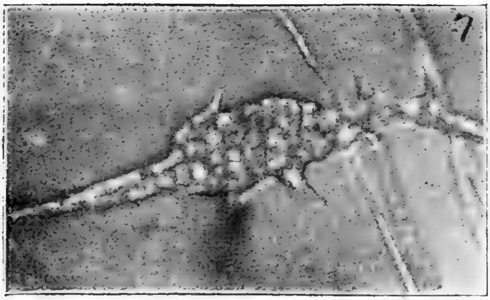
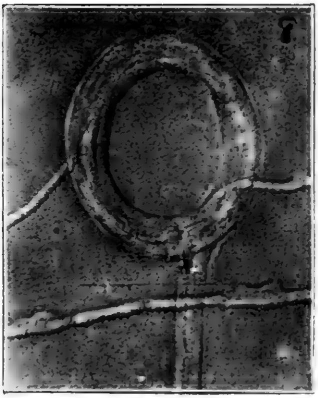
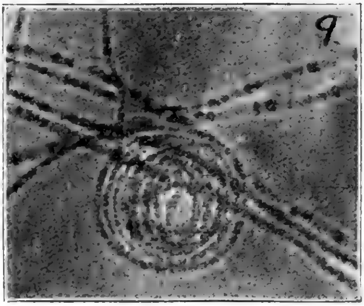
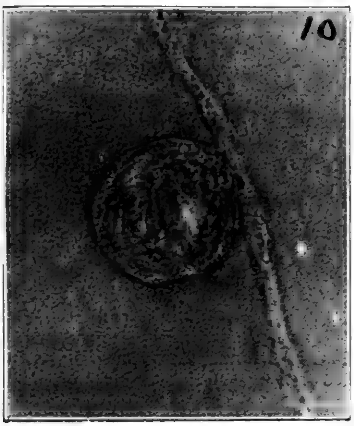








Curtiss on Red Mould.

Affinities of the Mycetózoa. By Edgar W. Olive.

The chief interest which invests this group of low organisms lies in the fact that the individuals possess a dual relationship; during one stage of their existence resembling certain members of the animal kingdom, while during another, they bear many resemblances to the plant kingdom, through the fungi, with which they agree somewhat in the structure of their organs of reproduction and spores.

The spores, on germinating, produce swarm-cells and plasmodia, instead of mycelium. The swarm-cells, or myxamœbæ, resemble the naked amœbæ of the animal kingdom, while the remarkable plasmodium, although there is no parallel among undoubted animals, seems to partake almost wholly of characters agreed by scientists to be clearly animal.

The sporangium has a membranous wall sometimes resembling the cellulose walls of plants, and its cavity is filled with free spores and in many species a scaffolding support of threads called the capillitium. Probably the resemblance of this reproductive stage to the fungi is of very small amount, being confined to purely external resemblances.

The *Mycetozoa*, as defined by DeBary, embraces two distinct groups, the *Myxomycetes* of Wallroth, and in addition the *Acrasieæ* of Van Tieghem, evidently resembling each other very closely in the fact that their spores send forth swarm-cells which exhibit amœboid movements. The only important difference between the two is the formation of plasmodia by the coalescence of swarm-cells in the former and the formation of pseudoplasmodia by the aggregation of the swarm-cells in the *Acrasieæ*. It was regarded by DeBary as easy to conceive of the common origin of these two closely related groups or of the development of the one from the other. He says that probably the *Myxomycete* plasmodium was evolved from the aggregation plasmodium, since the latter appears to be the less complex form and its fructification much simpler; possibly the development took place in the converse order.

Botanists seem never to have questioned the homology of the pseudoplasmodium of the *Acrasieæ* with the plasmodium of the *Myxomycetes*. This plasmodium is strictly vegetative; during this period nourishment is imbibed. The pseudoplasmodium is not vegetative; it is simply preliminary to the reproductive stage by the aggregating of individuals. It follows, then, the strictly vegetative stage. If lack of analogy can thus be reasoned into lack of homology, the pseudoplasmodium and plasmodium may not correspond in type of structure.

To DeBary's oft-quoted, but rather ambiguous statement of his estimate with regard to the position of the *Mycetozoa* is due much of the unsettled condition of the group. He says: "I have since the year 1858 placed the *Myxomycetes* under the name *Mycetozoa* outside the limits of the vegetable kingdom, and I still consider this to be their true position." Strangely, however, he included the *Mycetozoa* in all his subsequent botanical works, as if he lacked the courage of his convictions; and other writers of text-books have continued to do the same.

DeBary based his views on his belief that the *Mycetozoa* in their evolutionary development are the terminal members of a series of forms. In his opinion they, like the puff-balls, do not connect with any higher group. He contented himself, then, with seeking for their possible affinities with the inferior forms from which they must have proceeded. Even in this search, he found it impossible to establish exact homologies, for he limited himself to strict resemblances in form, structure, and mode of life. All agree with his conclusions concerning the original starting point; that we are led by a very short step to the naked *Amœbæ* of the animal kingdom. The *Amœbæ* are organisms having the amœboid movements of the swarm-cells of the *Mycetozoa*, which multiply similarly by successive division, but which do not form plasmodia or aggregations in any way. Indeed, in *Sappinia*, which Dangeard places among the *Acrasieæ*, the *Amœbæ* do aggregate at the ends of straws. *Guttulina*, one of the *Acrasieæ*, is really a naked Amœba, differing only in the aggregation of its microcysts into heaps, or sori.

Bütschli has pointed out the probability of the starting point of the naked amœbæ being groups of very simple organisms known as the *Flagellatæ*; and since the swarm-cells of the *Mycetozoa* are furnished with cilia and have all the characters of the simpler *Flagellatæ*, DeBary goes back to these forms as the converging point of the plant and animal kingdoms.

Lister has established beyond a doubt the fact that certain of the *Mycetozoa* have the power of digesting solid food. In his experiments on the plasmodium of *Badhamia*, he proved that it had a remarkable power of discriminating between different foods. He suggests also that another species, *Chondrioderma difforme*, probably uses bacteria as its principal food. He has repeatedly seen them caught by the pseudopodia of the swarm-cells, ingested in the vacuoles, and gradually dissolved.

Yet, notwithstanding the fact that there are some exceptions to the rule, DeBary definitely states that "the food is taken in during the swarm-cell condition only in the fluid state or state of solution, and this is also the case, at least in most instances, with the plasmodia."

It is quite evident, as Massee has shown, that DeBary deduced all his reasons against the vegetable nature of these organisms from the vegetative stage. In his monograph on the group, Massee combats step by step the position taken by DeBary. He gives the following arguments in support of his views: (1) The frequent presence of cellulose in the cell walls of spores and sporangia; (2) the frequent separation from the protoplasm, during the period of spore formation, of a substance homologous with the substance separated during the same period in the *Ascomycetes*, etc. This forms the capillitium. (3) The frequent separation of lime from the protoplasm at the commencement of the reproductive stage. (4) Agreement with many fungi in contrivance for spore dissemination. (5) The production by free cell formation of spores protected in the early stage by a wall of cellulose, which eventually becomes differentiated, and, as stated by DeBary, "behaves toward reagents in a similar manner to cuticularized plant cell-membranes and to spore-membranes in the fungi." (6) The analogy with undoubted members of the vegetable kingdom, as *Hydrodictyon*, where the naked motile swarm-cells coalesce to form a net.

Massee claims that the observations upon the vegetative stage alone furnish no more convincing proof that the phenomena peculiar to it are incompatible with a condition of vegetable organisms than are the amoeboid forms in such algæ as the *Volvocineæ*.

The presence of cellulose in the stalk cells and spore walls of the *Dictyosteliaceæ* may be adduced as an argument for the plant affinities of the higher *Acrasieæ*.

Thaxter suggests another possible line of genetic connection of the *Mycetozoa* with plants, through the *Myxobacteriaceæ*. He places the *Myxobacteriaceæ* in the *Bacteria*, or *Schizomycetes*, on account of the homologies in the reproduction which they present. In one stage they are a mass of rods, having a slow progressive motion and reproducing rapidly by fission. They are distinguished, however, from other bacteria by having two definitely recurring periods in their life cycle—"one of vegetation, the other of fructification or pseudofructification through the simultaneous and concerted action of numerous individuals." During the nutritive stage, the rods lie separate. Through some contagious impulse they concentrate toward central points, piling up on one another, and gradually change into spores.

As is cautiously suggested, "the resemblance (to the *Acrasieæ*) might be purely accidental," yet the general character of the corresponding periods is practically identical, except for cell differences of the organisms concerned.

If we assume that the pseudoplasmodium of the *Myxobacteriaceæ* indicates a genetic connection with that of the *Acrasieæ*, then the *Mycetozoa* have affinities with higher plants through the *Bacteria*, which are evidently derived forms of the fission-algæ. At any rate, as suggested by Thaxter, "caution is necessary in accepting the views of those who would unceremoniously relegate the *Mycetozoa* to the domain of pure zoölogy."

Morphological Characters of the Scales of Cuscuta.

By Alida M. Cunningham.

The work undertaken and the line of thought pursued throughout has been that of making a revision of the family *Cuscutaceæ* of North America. This work was commenced at the beginning of the present university year and has been pursued since that time with the assistance of Dr. Stanley Coulter of Purdue University. The only complete work on this family which has been given to the public is that of Dr. Engelmann, published in 1859. Since that time a few new species have been added to those named in his work, and some of these have been classified by Dr. Engelmann himself. Like all works of any magnitude, the original is imperfect and incomplete.

This family is one presenting much difficulty, because there are so few characters which can be used in determination and many of the flowers are so minute as to necessitate the constant use of the microscope in examination. For this reason much classification has been done in the past by mere comparison of the unnamed specimens with the named ones. After a study of these plants we are convinced that such a classification is misleading and extremely inaccurate. Again, the plants have such a range of variation, yet merge into each other so closely in some of their parts that it is only by the utmost care and closest scrutiny that they may be determined, and a dissection of the flower is invariably necessary. Many of the species have also a great similarity in habit of growth and the arrangement of the inflorescence, which is confusing and liable to mislead one who attempts a mere comparison.

The sketch here presented does not cover the subject originally undertaken, but is merely one of the many interesting features in this family of plants. This study of the scales of *Cuscuta* was suggested in the course of the study by reason of the fact that the observations made thus far do not, in many respects, coincide with the statements made by Dr. Engelmann in his work. He describes the scales as being epistamineal and that they are evidently lateral dilatations of the lower part of the filaments, or a sort of stamineal crown attached at the base of the corolla, but not a duplication of the corolla.

In the study of this subject we have made constant use of the microscope, making sections of flowers in various directions, and are forced to conclusions quite different from those of Dr. Engelmann. In the course of the work it was noticed that in some species the filament of the stamen extends under the apex of the scale, in others the base of the filament is above the apex of the scale, and in still others the filament can be traced nearly to the base of the corolla, while the scale forms two lateral wings, one on each side of the filament. For this work specimens from each of the three groups were examined. Longitudinal sections were made through the corolla, with its attached stamen and scale, and a careful study showed that the scales have their origin from the corolla. The stamens also originate from the corolla, but at a different level from the scale, so that they cannot possibly be attached to each other. However, in the third section a few species showed some connection between the scale and the filament; but while there may have been a slight attachment of these parts in individual specimens, yet the examination of other sections fully demonstrated the fact that the origin of the scale is unquestionably from the corolla, and the base of the stamen is slightly above that of the scale.

The results of these examinations, so far as made, confirm us in the belief that the scales are not epistamineal, and do not form a stamineal crown, but are petaloid in their origin and are in the nature of a duplication of the petals.

Geographical Distribution of the Species of Cuscuta in North America.

By Alida M. Cunningham.

In the Year Book of the Agricultural Department, published in 1894, C. Hart Merriam, Chief of the Division of Ornithology and Mammalogy, gives a revision of the work theretofore done in an endeavor to divide the country into distinct zones according to the plant and animal life found therein. And, since the distribution of all life depends so completely upon rainfall and temperature, these have been made the principal guides in locating the lines separating these zones, taking into consideration both latitude and elevation. He has divided North America into five zones as follows: Boreal, Transition, Upper Austral, Lower Austral, and Tropical.

In the course of the study for the purpose of making a revision of the genus Cuscuta it was found of interest to note the geographical distribution of the genus in accordance with the plan adopted by Mr. Merriam. So far as the work has progressed, the material examined has been that contained in the herbaria of Harvard University, the botanical gardens of St. Louis, Missouri, and Purdue University, in all about 450 specimens. Among them, according to the nomenclature heretofore adopted and still in use, we find thirty-two species and seventeen varieties, which are distributed throughout the five zones in the manner given below. But there is found here the same difficulty that has confronted us on different occasions before, *i. e.*, that the forms are so badly confused at present that any arrangement which might be made now is almost sure to need revision after a critical study of the genus. According to the present nomenclature, the distribution is as follows:

Potosina, *Palmeri*, *Americana*, *corymbosa*, *tinctoria*, *Jalapensis*, *mitræformis*, *floribunda* and *gracillima* are confined to the tropical zone and constitute the greatest number found in any one zone.

The next greatest number found in only one zone is in the Transition. They are *Epithymum*, *denticulata*, *rostrata* and *epilinum*.

Californica and *subinclusa* are found in the Tropical and Transition.

Leptantha and *chlorocarpa* in the Upper Austral and Transition.

Applanata and *inflexa* in the Upper Austral.

Cuspidata, *compacta*, *decora*, *Gronovii* and *arvensis* are distributed over the Upper Austral, Lower Austral and Transition.

Squamata and *odontolepsis* in the Tropical and Upper Austral.

Tenuiflora is found in three zones, i. e., the Transition, Upper Austral and Boreal.

Glomerata in the Upper and Lower Austral.

Umbellata in the Tropical, Upper and Lower Austral.

Obtusiflora in the Tropical, Transition and Upper Austral.

Salina in the Transition and Boreal.

Exaltata is found only in the Lower Austral.

The above facts may be presented in tabular view as follows:

Boreal.	Transition.	Upper Austral.	Lower Austral.	Tropical.
Salina.	Salina.			
Tenuiflora.	Tenuiflora.	Tenuiflora.		
		Glomerata.	Glomerata.	
	Californica.			Californica.
	Subinclusa.			Subinclusa.
		Umbellata.	Umbellata.	Umbellata.
	Obtusiflora.	Obtusiflora.		Obtusiflora.
	Epithymum.			
	Epilinum.			
	Denticulata.			
	Rostrata.			
		Squamata.		Squamata.
		Odontolepis.		Odontolepis.
			Exaltata.	
		Inflexa.		
		Applanata.		
	Cuspidata.	Cuspidata.	Cuspidata.	
	Compacta.	Compacta.	Compacta.	
	Decora	Decora.	Decora.	
	Gronovii.	Gronovii.	Gronovii.	
	Arvensis.	Arvensis.	Arvensis.	
				Potosina.
				Palmeri.
				Americana.
				Corymbosa.
				Tinctoria.
				Jalapensis.
				Mitræformis.
				Floribunda.
				Gracillima.
	Chlorocarpa.	Chlorocarpa.		
	Leptantha.	Leptantha.		

Notes on the Germination and Seedlings of Certain Native Plants.

By Stanley Coulter.

In the study of the phanerogamic flora of the State, some problems respecting the distribution or rather the non-distribution of certain species seemed to require for their solution somewhat extended germination experiments. These experiments have been in progress for three years, under conditions to be indicated later.

Incidentally the seedlings were carefully studied, more especially as to their resistance to temperature and moisture changes, in a less degree as to the form and arrangement of their earlier foliage leaves, since these, perhaps, in many cases may be regarded as representing inherited forms, while the later leaves stand for adaptive responses to light intensity and other ecologic factors. The results of the observations upon this point have not been sufficiently considered to warrant their presentation at this time, except in a few instances which indicate that many suggestions as to relationships would probably be one of the results of such a study.

It will be recalled, when we consider our native plants, that the increase in numbers and the consequent amount of territory occupied by any specific form bears no direct relation to the number of seeds it may produce. Indeed, the production by a given plant of a vast number of seeds, with adaptations for a wide dispersal, should, perhaps, be taken as an index of the intensity of its struggle for existence, and stand as a sure sign that, save through some change in ecological factors, the form will do little more than maintain itself in nature.

This view, which it will be remembered was advanced by Weismann, is being confirmed by observations upon plants. The setting of a large number of seeds stands not as the sign of a rapid increase in numbers of the form, but rather the reverse. An example or two may emphasize the statement.

The common nightshade *(Solanum nigrum)* is a plant with which all are familiar. Where it obtains a foothold it usually holds its own, but rarely becomes dominant or so increases in number from year to year as to attract attention. From one of these plants which bore forty-three berries and was still flowering, I took three berries and planted them after having broken the outer walls. *One hundred forty-two* seedlings appeared. Surprised at the result I planted three other seedlings similarly treated, being especially careful to eliminate error. In this case *one hundred eighty-seven* seedlings appeared. This would indicate that each berry contained on an average at least fifty viable seeds, and as there were over forty berries, the potential product from that single plant was over two thousand plants.

From the ordinary *Scrophularia*, germination percentages ran from fifty-six to seventy in the favorable conditions of the laboratory, indicating an almost incredible possible increase from a single plant. Yet every botanist knows that this plant makes no visible increase in numbers from year to year. The great number of capsules filled with seeds is but the sign of its intense struggle.

In many cases the causes which hold in check the undue increase of a specific form are evident. The law requiring that stock should be kept within bounds, modified in very marked degree the flora of the State, and in certain regions has served to cover stripped hills with a new timber growth. But there are cases in which the number of seeds produced is so enormous, the means of dispersal so various and ingenious, and the dispersal itself so sure, that we wonder that the increase is no more rapid. In this category we find notably the composites. Considering their myriads of seeds and their perfect means of seed dispersal, their increase in numbers is insignificant. Indeed, in many cases special protective devices have been developed in order that they may maintain their place in nature.

It is evident that factors other than those ordinarily limiting plant distribution are operative in limiting the distribution of the composites, or that the composites are peculiarly sensitive to conditions which do not materially affect the majority of plants. The theory of special limiting factors seemed scarcely worthy of consideration. It was therefore presumed that some, at least, of the ordinary factors were more effective than in other cases, and that in all probability there was a peculiar sensitiveness to these changes at some particular stage of development. The experiments were undertaken with the hope of throwing some light upon these points. The conditions of the experiments have been varied from time to time as experience suggested, and to such an extent as to preclude tabulation in the limits of this paper. Conditions may be summarized as follows: Two kinds of soil were used—a loam mixed with sand and a leaf-mold. In both cases the soil was carefully sifted and packed in the pots in order to prevent subsequent settling. As regards moisture, three conditions were used—saturated, moderately moist and extremely dry. The percentage of water in the soil was not carefully worked out, but was roughly estimated to range from 25 per cent. in one extreme to between 80 and 90 per cent. in the other. Planting was either surface or at about the depth of the seed. The average temperature in the first series of experiments was 26.5° C., with extremes of 20° C. and 31° C. In the second and third series the average temperature was 24° C. As far as could be determined by inspection only perfect seeds were used. As a matter of course, control experiments served as checks upon results.

From the results of the experiments the following conclusions seem deducible.

First.—*The germination percentage in the compositæ is low as compared with that of the other families examined.*

This statement has its apparent exceptions in *Arctium Lappa* and *Cnicus lanceolatus,* which show high percentages. That these are exceptional, however, will be shown later. From the experimental cards the following table is drawn:[1]

	Per cent.
Arctium Lappa	93.3
Cnicus lanceolatus	89.3
Bidens bipinnata	37.5
Bidens frondosa	30.0
Lactuca Canadensis	37.5
Lactuca Scariola	25.0
Solidago Canadensis	12.5
Anthemis cotula	12.5
Cnicus muticus	10.0
Aster Shortii (one year)	
Ambrosia (one year)	
Vernonia fasiculata (one year)	

Germination percentages shown by forms in other families are as follows:

Solanum nigrum, 187 seedlings from three berries.

	Per cent.
Datura Tatula	100.0
Abutilon Avicennae	89.0
Scrophularia nodosa	70.0
Plantago Rugellii	62.5
Rumex Acetosella	56.7
Malva rotundifolia	45.0
Capsella Bursa-pastoris	45.0
Nepeta Cataria	
Chenopodium album	

[1] These are taken from over 200 experimental cards and are fairly typical of the series, Experiments with ordinary germinating apparatus confirmed these results.

These percentages are not exceptional, having been repeatedly obtained. I have not been able to secure germination in Chenopodium, a fact possibly due to the late collection of the material.

SECOND.—*In most cases the achenes show the highest germinating percentage if collected at about the middle of the flowering season.*

If, for example, the flowering period is from July to October, achenes collected in the latter part of August or first of September will give a higher germinating per cent. than those collected at any other season. This is true in all forms studied, with the exception of *Arctium.* The non-viability of the later achenes may be explained as due to the action of frost. That of the earlier achenes is not so readily explained. In *Arctium* the achenes show a ready viability at all seasons. In the case of Bidens it is possible that the later achenes might show a fair percentage of viability, as no late collections of this genus were made. The difference in viability at different floral periods does not seem to exist in the other families studied. On the contrary, in the case of Abutilon and Solanum, the highest percentages were obtained from the seeds collected very early in the season.

THIRD.—*For the most part the central achenes of the head are not viable, and the same condition is frequently found in the outer rows.*

In all cases the largest germination percentage was obtained from achenes taken about midway between the center and periphery of the head. An exception to this statement is perhaps found in Helianthus, in which, in a single experiment, the central achenes were found to show a high germination percentage. A consideration of the order of maturing of the flowers in the composite head taken in connection with the mode of pollination furnishes the probable explanation of this fact.

FOURTH.—*The seedlings of all composite forms studied, were found to be particularly sensitive to both temperature and moisture changes.*

Very slight changes in either of these conditions, especially if sudden, proved fatal almost without exception. An increase in temperature of 5° C., brought about in thirty minutes and continued for three hours, killed all the seedlings of Bidens, Cnicus, Lactuca, Solidago and Anthemis, the only composite seedlings escaping being those of Arctium. In the case of the other forms, Scrophularia alone succumbed, Abutilon, Malva, Solanum, Datura and Capsella not being visibly affected nor apparently retarded in their growth.

A similar temperature change, brought on gradually (three hours) and continued for three hours, only produced about a 40 per cent. fatality among the composites.

Changes in moisture, either in the soil or in the air, found a ready response in the behavior of the composite seedlings. A diminution of moisture, which would not even produce wilting in the seedlings of other families, would not infrequently prove fatal to those of the composites. The effect of moisture increase was not so readily seen, although there exists under such conditions a tendency on the part of the stem of the seedling to rot near the ground, a tendency apparently shared by Abutilon, and which seems about the only check put upon the increase of this latter form.

As might be expected *direct sunlight* works against the seedlings of composites, as, indeed, against all others, but with a peculiarly fatal effect in these sensitive forms. It has been found necessary in all cases to protect them from the direct sunlight for several days, usually until after the development of the first foliage leaves. Such extreme sensitiveness was rare, if at all present in the other families studied.

FIFTH.— *Cotyledon leaves of nearly related forms closely resemble each other, a resemblance often carried on in the earlier true leaves.*

The cotyledon leaves of Arctium, Cnicus lanceolatus and Cnicus muticus are almost exactly alike. The only dissimilarity observable being that in Arctium the green is a trifle darker than in Cnicus. The resemblance is so exact that I discarded the first germination experiments with Cnicus, supposing that through inadvertence Arctium achenes had been planted. With the appearance of the first true leaves Arctium is plainly marked off from Cnicus, but the two species of Cnicus are not to be separated until the appearance of at least the third foliage leaf. By this statement I mean that I think that at this point I can detect the beginnings of the leaf characters of the forms. The same conditions are found in the Lactucas. Scariola cannot be separated from Canadensis in any of the seedling stages so far as my observations go, indeed, though I carried the seedlings through the development of the seventh foliage leaf I found no marked indication of specific foliar differences. I think, without multiplying instances, that in very many cases supposed relationships between the species of a large genus, and certainly between many genera, might find corroborative evidence in a study of the early foliage of the seedlings.

SIXTH.—*In most cases the highest germination percentages in composites are obtained from surface planting in leaf mold.*

Arctium is the exception to this statement also. By surface sowing upon leaf mold, under the three conditions of moisture, Arctium gave an average germination percentage of 22.2 per cent. In sandy loam, where the achenes were covered by sifting earth over them, the percentage rose to 93.3 per cent. In all other cases, however, the leaf mold gave much the larger per cent. This was especially marked in the case of Cnicus lanceolatus, in which in sandy loam the percentage was 12.5, while in leaf mold the average percentage was 89, rising in one case to 100 per cent. The experiments indicate strongly that successful germination in composites is more closely dependent upon the character of the soil than is the case in the majority of our native plants. In other words, their soil range is so narrow that a slight modification in its character may practically prevent germination of the achenes and thus very effectually limit distribution.

SEVENTH.—*The water content of the soil does not* (so far as is indicated by these experiments), *affect the germination percentage to the degree that might have been expected.*

While differences in the water content of the soil affects the seedlings in a marked way, germination is unaffected under a wide range in water content of the soil. In extreme cases, some forms show marked variations. Arctium, for example, which gives a germination percentage of 93.3 under ordinary soil moisture conditions, falls to 3.3 per cent. in the case of extreme dryness. Cnicus lanceolatus, on the contrary, rises to 100 per cent. in extremely dry soil. In the forms studied the highest percentage of germination is found under moderately moist conditions, and the lowest under extremely dry conditions, save in the case of Cnicus lanceolatus, where the reverse seems to be true. Extreme soil moisture in many cases leads to the moulding of the achenes.

A careful dissection of material used in these experiments showed that there was nothing in the character of the achenes themselves to which this low germination percentage could be attributed. The material was collected with care expressly for these experiments, and dissection demonstrated well formed embryos in more than 80 per cent. of the achenes examined.[2] I am, therefore, led to believe the low germination

[2] The achenes thus examined were taken from the portion of the head indicated in conclusion three, *supra*.

percentages to be due to changes in external conditions, to which, perhaps, the forms are peculiarly responsive. The ease and certainty with which high germination percentages were secured in other families certainly lends support to the view.

The experiments are still in progress, as there are still many points to be worked out in detail. Among them are the effects of varying soil temperatures, of a wider range of soils, of progressive experiments for the determination of resting periods in the various forms, of duration of viability, of the effect of freezing, and others self-suggestive to the experimentalist. Until these are worked out in detail the question as to the causes of the relatively small distribution of any given composite form must remain open. So far as the experiments go they point to this limitation being due in a very large degree:

1. To a low germination percentage, largely due to an extreme sensitiveness on the part of the embryo to external conditions, to which should perhaps be added imperfect pollination, due to causes already given.

2. To an extreme sensitiveness of the seedlings to temperature and moisture changes, either in soil or atmosphere. This necessarily brings about a peculiar sensitiveness to direct sunlight.

When the habits of most of our native composites are considered it will be seen that this extreme sensitiveness in both achene and seedling proves an effectual limitation to their distribution. Other factors than these here emphasized enter, but none are of such general application.

Formalin as a Reagent in Blood Studies. By Ernest I. Kizer.

Among the most common reagents used in the demonstration of blood corpuscle structure, are found osmic acid, salt solutions, picric acid and acetic acid. But all of these cause distortions of the corpuscles, so they are imperfect fixing agents and preservatives. The method of drying blood on the coverslips is seldom successful in the hands of beginners.

Formalin has been found very useful in this connection, both as a fixing agent and as a preservative, because it produces no appreciable distortion of corpuscles, does not interfere with staining, is easily operated and preserves blood perfectly, at least, for several months.

The method consists of the following steps:

1. Mix one volume of perfectly fresh blood with three volumes of a two per cent. solution of formalin.

2. Allow the mixture to stand at least an hour; then draw a small quantity from the bottom of the vessel with a pipette, by which a drop is transferred to a clean coverslip; spread evenly over the coverslip and allow the liquid to evaporate. The method of pressing the coverslips together, as in sputum analysis, is to be preferred.

3. Pass the coverslips through the flame, films uppermost, in order to cement the corpuscles to the glass.

4. Dip into a five per cent. solution of acetic acid once or twice.

5. Remove the acid with water.

6. Stain. Perhaps the best stain for non-nucleated corpuscles is Gentian violet (a two per cent. solution; time of staining, about two or three minutes). For nucleated forms, contrast stains, as Methyl blue and Gentian violet, or Hæmatoxylin and Eosin, or Methyl green and Safraum, give very good results. Ehrlich's Triple stain may be used for human corpuscles.

7. Wash out excess of stain with water or alcohol as the stain requires.

8. Remove alcohol with clove oil or xylol, and

9. Mount in Canada Balsam.

This method proved very successful in the laboratory of Purdue University, and was used in studying five different forms of corpuscles. They were those of the cat, the ox, the pigeon, the chicken, and man. The human corpuscles were the only ones which resisted the stains, but this difficulty was overcome by the use of a weak solution of acetic acid. Besides making the stains effective, it also clears the films considerably. Although this method may be of no chemical value it promises to be successful for general laboratory purposes.

Species of Diptera Reared in Indiana During the Years 1884 to 1890.

By F. M. Webster.

The following species of Diptera were reared by me while located in Indiana, as Special Agent of the U. S. Dept. Agr., Div. Ent., and are given here as finally determined by Mr. D. W. Coquillett in Bulletin 10, N. S., and Bulletin 7, Technical Series, both of the Division of Entomology.

FAMILY TACHINIDÆ.

Euphorocera claripennis Macq., reared at Lafayette from caterpillars of *Datana contracta* Walk. On one of these larvæ were 213, and on a second 228 eggs of these flies.

Frontina frenchii Will., reared at Lafayette, from caterpillars of *Ichthyura inclusa* Hueb., and also from the larvæ of *Pyrameis cardui* Linn.

FAMILY BOMBYLIIDÆ.

Anthrax hypomelas Macq. This was reared in numbers from the larvæ of *Agrotis herilis*, cutworms, that were excessively abundant in a cornfield near Lafayette, in 1889. See Insect Life, Vol. II, pp. 353–4.

FAMILY OSCINIDÆ.

Meromyza americana Fitch. This occurs throughout the entire State, the larvæ attacking wheat and rye. I reared it from material secured at Oxford, and also from New Harmony.

Chlorops ingrata Will. This species was reared from gall-like swellings on tips of *Muhlenbergia mexicana*. The galls were collected at Oxford, in August, and the adults issued the following May and early June.

Elachiptera longula Loew. This was reared from the stems of *Panicum crus-galli*, within which the larvæ feed, at Oxford, in 1884, and also from fall wheat at Lafayette, in July, 1890, and also from oats, in 1886.

E. nigricornis Loew. and *E. costata* Loew. were also reared with the above in the fall wheat.

E. nigriceps Loew. was reared from *Panicum crus-galli* at Oxford, in September, 1884.

Oscinis trigramma Loew. Reared at Lafayette in July, from volunteer wheat plants. *O. coxendix* Fitch, was reared also with the above.

O. soror Macq., was reared at Oxford, from *Panicum crus-galli*, in October, 1884, and also from the stems of *Poa pratensis*, at Lafayette, in June, 1887.

Oscinis carbonaria Loew., was reared from young wheat plants at Oxford, September, 1884, and from wheat plants at Lafayette, in August, 1886, and again in August, 1888, and in July, 1890, among these last there being also specimens of *O. umbrosa* Loew.

FAMILY AGROMYZIDÆ.

Leucopis nigricornis Egger. Reared from larvæ preying upon *Siphonophora avenæ*, at Vincennes, June 26, 1889, the adults issuing in July, 1889. This is an imported species, as it occurs all over the United States, and has been reared from *Pemphigus* in France.

Ceratomyza dorsalis Loew. Reared from larvæ mining in the leaves of timothy, at Lafayette, in 1888, and also from larvæ mining in the leaf sheaths of wheat.

Agromyza æneiventris Fall. Reared from larvæ burrowing in the stems of white clover, *Trifolium repens*. See Report Commissioner of Agriculture, U. S., 1886, p. 582.

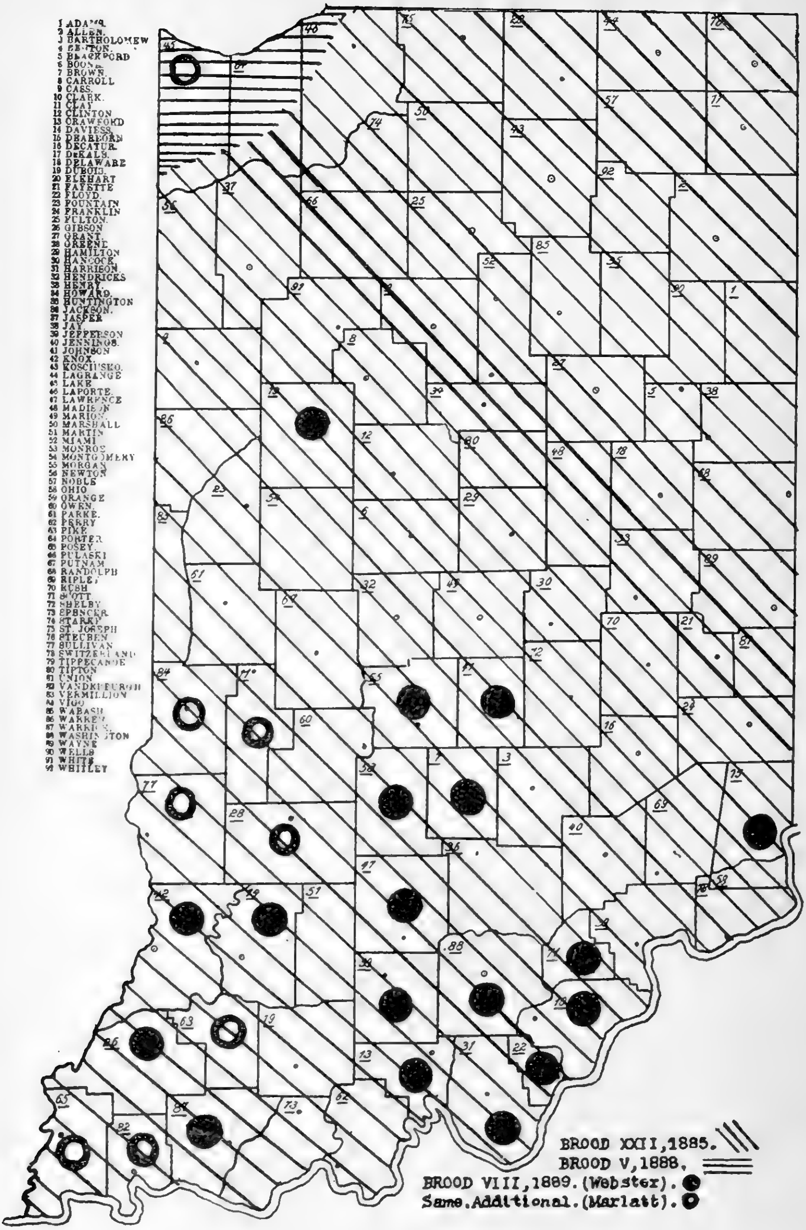
Distribution of Broods XXII, V and VIII, of Cicada septendecim, in Indiana. By F. M. Webster.

It was my good fortune, while located at Lafayette, Indiana, during the years 1884-90, as a special agent of the United States Department of Agriculture, Division of Entomology, to have an opportunity of studying the distribution of these three broods of the periodical cicada.

On consulting the accompanying map and explanation thereto, it will be observed that Brood XXII, 1885, covers the entire State, except a small area around the lower extremity of Lake Michigan. This strip of country is much narrower at the Michigan line than it is at the Illinois line, including as it does only the extreme northwest corner of Laporte county, the dividing line between this and Brood V being, here, between the village of Otis and the city of Laporte, crossing the line of Porter county about Wanatah, and passing across Lake county, in the vicinity of Orchard Grove.

This is the strongest of all the broods in Indiana and covers by far the greatest area. Its next recurrence will be in 1902.

Brood V covers only the area over which Brood XXII did not occur and does not, so far as I was able to learn, overlap that brood. It covers a


1 ADAMS.
2 ALLEN.
3 BARTHOLOMEW
4 BENTON.
5 BLACKFORD
6 BOONE.
7 BROWN.
8 CARROLL
9 CASS.
10 CLARK.
11 CLAY.
12 CLINTON
13 CRAWFORD
14 DAVIESS.
15 DEARBORN
16 DECATUR.
17 DeKALB.
18 DELAWARE
19 DUBOIS.
20 ELKHART
21 FAYETTE
22 FLOYD.
23 FOUNTAIN
24 FRANKLIN
25 FULTON.
26 GIBSON
27 GRANT.
28 GREENE.
29 HAMILTON
30 HANCOCK.
31 HARRISON.
32 HENDRICKS
33 HENRY.
34 HOWARD.
35 HUNTINGTON
36 JACKSON.
37 JASPER
38 JAY.
39 JEFFERSON
40 JENNINGS.
41 JOHNSON
42 KNOX.
43 KOSCIUSKO.
44 LAGRANGE
45 LAKE
46 LAPORTE.
47 LAWRENCE
48 MADISON
49 MARION.
50 MARSHALL
51 MARTIN
52 MIAMI
53 MONROE
54 MONTGOMERY
55 MORGAN
56 NEWTON
57 NOBLE
58 OHIO
59 ORANGE
60 OWEN.
61 PARKE.
62 PERRY
63 PIKE
64 PORTER
65 POSEY.
66 PULASKI
67 PUTNAM
68 RANDOLPH
69 RIPLEY
70 RUSH
71 SCOTT
72 SHELBY
73 SPENCER
74 STARKE
75 ST. JOSEPH
76 STEUBEN
77 SULLIVAN
78 SWITZERLAND
79 TIPPECANOE
80 TIPTON
81 UNION
82 VANDERBURGH
83 VERMILLION
84 VIGO
85 WABASH
86 WARREN
87 WARRICK
88 WASHINGTON
89 WAYNE
90 WELLS
91 WHITE
92 WHITLEY
BROOD XXII, 1885.
BROOD V, 1888.
BROOD VIII, 1889. (Webster).
Same. Additional. (Marlatt).

small portion of Laporte county and the greater portion of Porter and Lake counties, and will reappear next in 1905.

Brood VIII is almost entirely confined to the southern counties and was really very abundant in 1889 only in Harrison county. I have indicated by a dot on the map the localities where I know from personal knowledge the insect occurred, to which localities Mr. C. L. Marlatt, in Bull. 14, N. S., U. S. Dept. Agr., Div. Ent., has added others which I have indicated by a **O**. The occurrence in Tippecanoe county was at Lafayette, a single female having been found by one of the sons of Dr. E. Test of Purdue University. This is the weakest in point of numbers of the three broods, and will in time become totally extinct, largely, at least, owing to the attacks of the English Sparrow, *Passer domesticus*. It will next appear in 1906.

Some Insects Belonging to the Genus Isosoma, Reared or Captured, in Indiana. By F. M. Webster.

Isosoma grande Riley. This was reared from wheat at Oxford and Lafayette, and was the first proof secured of the presence of a dimorphism, and alternation of generations in *Isosoma tritici*, as it was then known, the latter being now known as *minutum*, the wingless spring and winter generation; and the former as the winged, summer generation, the one having been bred from the eggs of the other by myself.

Isosoma captivum Howard. Captured from *Poa pratensis* at Lafayette. Type.

Isosoma maculatum Howard. Captured with the preceding. Type.

Isosoma tritici Fitch. Reared at Lafayette and elsewhere, and collected on grass at Lafayette.

Eurytomocharis eragrostoidis Howard. Reared at Lafayette from the stems of *Eragrostis poœoides*. Type.

For descriptions of these species, as well as illustrations of them, see Bulletin No. 2, Technical Series, Division of Entomology, U. S. Dept. Agr., by Dr. L. O. Howard.

Lake County Crow Roosts. By T. H. Ball.

[Abstract.]

The main roosting places in these later years, so far as ascertained, are two. One is five miles south of Crown Point, in a pine grove covering an area of about four acres on a large farm well out, in what was once a wide and open prairie. For several years the crows were there in large numbers, but some three years ago boys shot into the roost and drove them away. They have returned. Mrs. George Schmall estimates the number roosting there at one thousand.

This grove is a "wind breaker," the trees, Scotch and Austrian pine, were set out very thick many years ago. It makes a grand shelter in the winter time. Many of these crows from this pine grove go in a south-easterly direction to find food in the Kankakee marsh region.

The second crow roost of the county is nine miles northwest of Crown Point on both sides of the "Panhandle" railroad, in groves of small oak trees, and one evergreen grove. I visited this locality Tuesday, December 27, 1898. About one mile from it I saw, at 2 p. m., two or three hundred crows feeding in a corn field. Reaching the farm house I learned that two or three pairs of crows selected these groves in 1875. The number of individuals in this colony now may be placed at two thousand. Many of them pass into Illinois to get food, passing in a southwesterly direction over Dyer, on the State line, mornings, sometimes two hundred in a flock.

The Distribution of Blood Sinuses in the Reptilian Head.

By H. L. Bruner.

[Abstract.]

The principal blood sinuses of the reptilian head are the following:

1. The intra-cranial sinuses, which were first described by Rathke[1] in 1839.

2. The nasal sinus, which surrounds the external naris and the nasal vestibule; it was observed and described by Leydig[2] in 1872.

3. The orbital sinus, which lies between the eyeball and its orbit. This sinus was first investigated by Weber[3] in 1877.

The development of the above-mentioned sinuses has been worked out by Grosser and Brezina[4] in the snake (Tropidonotus natrix).

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[1] Rathke: "Entwicklungsgeschichte der Natter (Coluber natrix)." Köenigsberg, 1839.

[2] Leydig: "Die in Deutschland lebenden Arten der Saurier." Tübingen. 1872.

[3] Weber: "Nebenorgane des Auges der Reptilien." Archiv für Naturgeschichte, 43 Jahrg., Band I.

[4] Grosser und Brezina: Morphologisches Jahrbuch., Band 23, 1895.

On the Regulation of the Supply of Blood to the Venous Sinuses of the Head of Reptiles, with Description of a New Sphincter Muscle on the Jugular Vein. By H. L. Bruner.

[Abstract.]

The remarkable development of blood sinuses in the reptilian head has received no explanation at the hands of earlier investigators. The work of the writer shows that the origin of these sinuses is due to periodical constriction of the jugular vein by a ring-like muscle, whose contractions thus lead to an increased blood pressure in the region drained by the vein.

In Phrynosoma this ring-muscle, which is composed of striated fibres, is attached to the lateral end of the ex-occipital bone, beneath which the jugular receives the posterior cerebral vein. Immediately behind the mouth of the latter vein, the ring-muscle embraces the jugular. The muscle occurs also in turtles (Emys) and snakes (Tropidonotus).

According to the observations of the writer on lizards, the distention of the extra-cranial blood sinuses is of great importance at the time of moulting, when the removal of the old epidermis is greatly facilitated by it, particularly in the region of the eyes and nasal openings. Under ordinary circumstances, such distention probably serves to express emotion of various kinds.

The above-mentioned facts furnish a basis for an explanation of the habit of ejecting blood from the eye (orbital sinus), for which Phrynosoma is noted.

For additional details, the writer refers to the paper itself, which will be published in full elsewhere.

Note on the Aberrant Follicles in the Ovary of Cymatogaster.*
By George L. Mitchell.

The thickness of the ovarian follicle varies in different vertebrates inversely with the size of the egg. In species containing large eggs the thickness of the follicle *decreases* relatively with the growth of the egg. In the bird and frog it is only in the smaller eggs that the single layer of follicle cells may be distinguished in sections. The rapid growth of the egg soon stretches this layer of cells so that it becomes finally indistin-

*Contributions from the Zoölogical Laboratory of the Indiana University, No. 25.

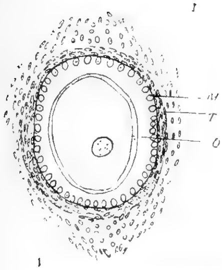
guishable. In species containing relatively small eggs the thickness of the follicle *increases* with the growth of the egg. Examples of this are found in fishes, but the extreme is found in the Graafian follicle of mammals.

The Graafian follicle, whose structure is well known, offers some peculiar features which may be explained in connection with the reduction of the size of the ovum in the mammalian phyllum. Suggestions as to how any why the many layered follicle of higher mammalia has arisen from the single layered follicles of monotremata are furnished by the viviparous fish Cymatogaster. The egg in this species is much below the average in size. It has in fact lost nearly all of its yolk. It is significant, therefore, that among many individuals with normal follicles there are occasionally found individuals containing a small number of many layered follicles. It is to call attention to these and to compare them with the mammalian structures that the present article is prepared.

In order to fully appreciate the conditions, follicles of various mammals and various stages in the same mammal may be briefly mentioned. Poulton has found that in monotremata the follicular epithelium remains a single row of cells.

The follicles of the cat, after moving from the surface toward the deeper parts of the ovary, begin to thicken from the single layered stage to the many layered stage. Fig. 1 represents the single layered stage. Fig. 2 represents the many layered stage in which the follicular cavity is beginning to be formed. The egg in the many layered stage is usually imbedded in the portion of the granulosa nearest the surface of the ovary. The first traces of the follicular cavity are seen in the thicker part of the granulosa. As the egg grows the follicle cells still multiply and the liquor folliculi filling the cavity distends the latter. Fig. 3 shows the follicle with its now nearly ripe egg imbedded in the discus proligerus. This figure represents the typical Graafian follicle.

The follicle of the rabbit differs from that of the cat (Fig. 4). Columns of granulosa cells connect the outer mass of cells with that surrounding the egg. In such follicles as many as four stalks are found in a single section. On examining other sections of the same follicle other stalks may be found so that a single follicle may contain as many as seven of these. In both the cat and rabbit the thickness of the follicular wall is not reduced with the growth of the egg, but rather increases proportionally with the growth. In the opossum both types of follicles of Figs.



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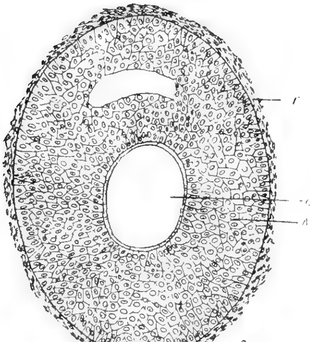

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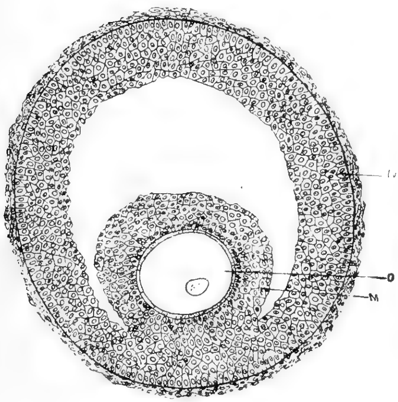

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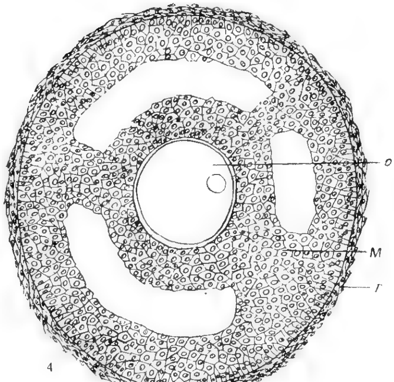

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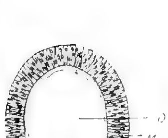

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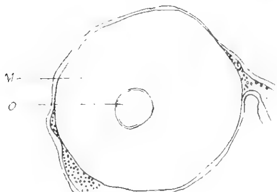

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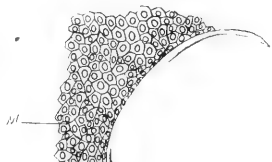

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3 and 4 were found. The two varieties were about evenly divided. Of the stalked variety there seemed to be few follicles with more than two or three pronounced cavities.

The normal follicle of Cymatogaster presents no novelties. As the egg ripens the granulosa cells become very high and narrow columnar, but remain in a single series.

As before stated, occasionally there are found, in this species, follicles in which the granulosa is made up of a great many layers of flattened and polyhedral cells. Such a one is represented in Fig. 6. Those cells immediately surrounding the ovum and those next the follicular wall are noticed to be somewhat flattened, while those intermediate are more rounded and polyhedral. The ovaries, which contain such follicles, are comparatively few, but where one such follicle is found, usually two or three more may be found. No indication of follicular cavities has been observed, but the similarity of such follicles to certain stages of the mammalian follicle is at once evident. Compare Fig. 6 with Fig. 2.

If, now, follicular cavities should be formed and filled by an accumulation of follicular fluid we should have conditions similar to those of Figs. 2 and 3.

In oviparous fishes, in batrachians, in birds, in monotremes and in the early stages of mammals, we find the follicles one layered. In the adult stages of marsupials and higher mammals, where the eggs are very small, we find the many layered condition.

The occasional multilayered follicle in the ovary of Cymatogaster, whose egg is but .2-.3 mm. in diameter, seems to bridge the condition found in normally large yolked eggs and the minute eggs of the higher mammals.

The material examined was collected by Dr. C. H. Eigenmann on the coast of California.

EXPLANATION OF FIGURES.

Fig. 1-3. Three stages in the development of the follicle of the cat.

Fig. 4. Follicle of the rabbit.

Fig. 5. Normal mature follicle of Cymatogaster.

Fig. 6. Abnormal follicle of Cymatogaster showing the small egg in the center of a many layered granulosa.

Fig. 7. Part of the granulosa layer of Fig. 6, enlarged.

Material for the Study of the Variation of Pimephales notatus (Rafinesque), in Turkey Lake and in Shoe and Tippecanoe Lakes.* By. J. H. Voris.

As a part of the general plan of the Indiana University Biological Station to study the variation of the same vertebrates in two contiguous lakes belonging to different water systems, I collected during the summer of 1895 a large series of Pimephales notatus in Turkey Lake and the Shoe and Tippecanoe Lakes. Shoe Lake is a small body of water perfectly land locked, but which has but recently become cut off from communication with Tippecanoe Lake. Tippecanoe Lake is a long narrow sheet of water near the head waters of the Tippecanoe River, a tributary of the Wabash. Turkey Lake occupies a corresponding position in the St. Lawrence system. At different points in Turkey Lake 536 specimens were collected in the months of June, July and August. In Tippecanoe, seventy-two specimens were taken, and in Shoe Lake, forty-three.

The species is much more abundant in Turkey Lake than in the other two lakes. Many individuals are found along the shallow rocky shores, and their eggs are found in abundance plastered on the under surface of boards and other submerged objects near the margin of the lake where the water is not more than one or two feet deep. The fry were seen in quiet, warm weather along the shores by the laboratory.

A large number of characters were examined at the beginning of the study, but as many of these, for one reason or another, were found not available for the purposes in hand, the data were finally limited to the number of dorsal and anal rays and to the scales of the lateral line. While this fish has the reputation of being very variable, the characters examined are remarkably constant, and in the number of dorsal and anal rays the species may be said to have reached a stage of stable equilibrium, as the following pages will demonstrate. Since it was not possible in every case to determine absolutely those scales in the lateral line which had and those which had not spores, this character is omitted from the paper.

A miscellaneous lot of 536 specimens from Turkey Lake range in length from 25 mm. to 73 mm. The largest number of individuals of a given length is 37 and these have a length of 47 mm. A curve constructed to show the relative number of specimens of a given length shows that they do not fall into distinct groups of different ages.

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*Contributions from the Biological Laboratory of the Indiana University, No. 19.

The dorsal fin has one spine-like ray, eight rays, the last one of which is double, and one very small or rudimentary ray before the spine. The variation from this is very small indeed. Of the 536 specimens from Turkey Lake, 97 per cent. have this number of rays, which may be designated thus: II 8½, the "II" standing for the rudimentary ray and spine, the "8" for the eight rays, and the "½" for the double of the last ray. The average number of rays is 8.0037. The table shows the results obtained.

DORSAL FIN.

No. of Rays.	*No. of Specimens.*	*No. of Rays.*	*No. of Specimens.*
II 8½	519	I 9½	1
II 9½	4	I 7½	1
I 8½	9	II 6	1
II 8	1		

It will be seen from the table that over one-half of those that vary from II 8½ are different only in the absence of the very small rudimentary ray. This is so small and lies so close to the base of the spine that it cannot be seen unless especially looked for. Only five specimens have nine full rays, one with seven and one with six, making in all but six specimens that have a variation of one full ray, and one a variation of two rays from II 8½.

The variation in the anal fin is a little more than in the dorsal, 92.91 per cent. have II 7½ rays. The anal fin has one less ray than the dorsal, and the average for the whole is 7.0037. The greater per cent. of variation in this fin is due to the absence of the rudimentary ray. Only four specimens have one complete ray more, and two one less than II7½. The table shows the results obtained.

ANAL FIN.

No. of Rays.	*No. of Specimens.*	*No. of Rays.*	*No. of Specimens.*
II 7½	498	II 6½	1
II 8½	3	I 6½	1
I 7½	30	I 8½	1
II 7	2		

The following table shows the dorsal and anal fins, together with the number of specimens that each combination contains. It will be seen from this table that there are but three specimens in which there is a variation from the prevailing number in both the dorsal and anal fins. Each of these has the small rudimentary ray absent, and one specimen has one complete ray more than the prevailing number. It seems that there is no co-ordination in the variation of these two fins. The per cent. of variation above or below the prevailing number in each case is so small that it may be regarded as purely accidental. At least it can be said that this fish in Turkey Lake has reached a stage of stable equilibrium as regards this character.

DORSAL AND ANAL FINS.

Dorsal.	*Anal.*	*No.*	*Dorsal.*	*Anal.*	*No.*
II 8½	II 7½	484	II 9½	II 7½	4
II 8½	I 7½	28	II 6	II 7½	1
I 8½	II 7½	7	II 8½	II 8½	3
I 8½	I 7	2	II 8½	I 6½	1
I 7½	II 7½	1	II 8	II 7½	1
I 9½	I 8½	1	II 8½	II 6¼	1
II 8½	II 7	2			

The dorsal and anal fins of seventy-two specimens from Tippecanoe Lake were examined and the results obtained are shown in the following tables:

DORSAL AND ANAL FINS.

Dorsal Fin.	*No. Specimens.*	*Anal Fin.*	*No. Specimens.*
II 8½	64	II 7½	69
II 9½	3	II 8½	2
II 7½	2	I 7½	1
I 8½	3		

DORSAL AND ANAL FINS COMBINED.

Dorsal Fin.	*Anal Fin.*	*No. Specimens.*	*Dorsal Fin.*	*Anal Fin.*	*No. Specimens.*
II 8½	II 7½	62	I 8½	II 7½	2
II 9½	II 7½	3	I 8½	I 7½	1
II 7½	II 7½	2	II 8½	II 8½	2

A comparison of these tables with the preceding ones shows that the per cent. of variation in the Tippecanoe specimens is much larger than in those from Turkey Lake. However, the number in the one case is not sufficient for a definite conclusion. Leaving out of consideration the small rudimentary ray, which would not be noticed in an ordinary examination, and considering only those cases in which there is a variation of at least one complete ray from the prevailing number, the per cent. in the dorsal fin of the Turkey Lake specimens is 1.3, while in those from Tippecanoe, it is 7. The per cent. of Turkey Lake specimens, that have a variation of at least one ray from the prevailing number in the anal fin, is 1.1, while in the Tippecanoe specimens it is 2.8.

Forty-three specimens from Shoe Lake were examined, and the results obtained are shown in the tables below:

DORSAL AND ANAL FINS.

Dorsal Fin.	*No. Specimens.*	*Anal Fin.*	*No. Specimens.*
II 8½	41	II 7½	40
I 8½	2	I 7½	2
		II 6½	1

DORSAL AND ANAL FINS COMBINED.

Dorsal Fin.	*Anal Fin.*	*No. Specimens.*	*Dorsal Fin.*	*Anal Fin.*	*No. Specimens.*
II 8½	II 7½	38	II 8½	I 7½	2
I 8½	II 7½	2	II 8½	II 7½	1

The number of specimens here is too small to draw any definite conclusions in comparison with the others. It is to be noticed, however, that there is but one case in which the variation from the prevailing number is one complete ray, and that occurs in the anal fin.

The scales in the lateral line of each side of 500 specimens from Turkey Lake were counted. They range from 40 to 48 in number, and the largest number of individuals have 44. The table below shows the number of individuals which have a given number of scales on each side. The striking thing shown by this table is the regularity of the variation on the right side. The largest number of individuals has 44 scales, and there is a range of four both above and below this.

	No. Scales Right Side.	*No. Specimens.*	*No. Scales Left Side.*	*No. Specimens.*
	40	3	40	1
	41	7	41	8
	42	36	42	45
	43	126	43	136
	44	157	44	168
	45	121	45	90
	46	37	46	40
	47	11	47	8
	48	2	48	4
Average	44.01		43.912	

On the right side the variation is nearly symmetrical. On the left side there is not such a marked symmetry. The number of specimens that have fewer than 44 scales on the right side is but one more than those that have more. On the left side, there are 190 that have fewer than 44 scales, and 142 that have more, a difference of 48.

The average deviation, or index of variability for the right is .9369, for the left, .94916.

In the following table every possible combination of scales for the two sides is given with the actual number of specimens for each combination in one column, and the number according to the laws of probability in a parallel column:

Scales.		Actual Number of Specimens.	Calculated Number.	Scales.		Actual Number of Specimens.	Calculated Number.	Scales.		Actual Number of Specimens.	Calculated Number.
Right.	Left.			Right.	Left.			Right.	Left.		
40	40	1	0	43	40	0	0	46	40	0	0
40	41	0	0	43	41	3	2	46	41	0	1
40	42	1	0	43	42	15	11	46	42	0	3
40	43	1	1	43	43	56	34	46	43	4	10
40	44	0	1	43	44	37	42	46	44	9	12
40	45	0	1	43	45	13	23	46	45	9	7
40	46	0	0	43	46	2	10	46	46	13	3
40	47	0	0	43	47	0	2	46	47	0	1
40	48	0	0	43	48	0	1	46	48	2	0
41	40	0	0	44	40	0	0	47	40	0	0
41	41	2	0	44	41	1	2	47	41	0	0
41	42	2	1	44	42	14	14	47	42	0	1
41	43	2	2	44	43	37	43	47	43	0	3
41	44	1	2	44	44	69	53	47	44	2	4
41	45	0	1	44	45	31	28	47	45	2	2
41	46	0	1	44	46	4	13	47	46	3	2
41	47	0	0	44	47	1	3	47	47	3	0
41	48	0	0	44	48	0	1	47	48	1	0
42	40	0	0	45	40	0	0	48	40	0	0
42	41	2	1	45	41	0	2	48	41	0	0
42	42	10	3	45	42	3	11	48	42	0	0
42	43	14	10	45	43	22	33	48	43	0	1
42	44	9	13	45	44	41	41	48	44	0	1
42	45	1	6	45	45	33	22	48	45	1	0
42	46	0	2	45	46	17	10	48	46	1	0
42	47	0	1	45	47	4	2	48	47	0	0
42	48	0	0	45	48	1	1	48	48	0	0

The two columns show that there is a striking deviation from the calculated results, the result of a marked correlation in the variation or tendency to or toward bilateral symmetry. As calculated, the chance association of the same number of scales on the two sides would occur 115 times for all combinations, it actually occurs 187 times. The specimens fall into several definite groups in which the same number of scales on each side forms the center of a group. This is not quite true at the extremes, but is especially marked in the central groups into which the large majority of the specimens fall. There are three specimens in the first group, each of which has 40 scales on the right side. One has 40 scales on the left side, one 42, and one 43. The greatest difference in the number on the two sides is three. There are three specimens in the first group of the calculated column. Each has 40 scales on the right side, one has 43 on the left, one 44 and one 45. The greatest difference in this case is five, and none have the same number on both sides. In the second group of the actual column there are seven specimens, two with 41 scales on each side, two with 41 on the right side and 42 on the left, two with 41 on the right and 43 on the left, and one with 41 on the right and 44 on the left. The greatest difference in the number of scales on the two sides is three. There are seven specimens in the second group of the calculated column. Each has 41 scales on the right side and on the left side one has 42, two have 43, two 44, one 45, and one 46. As in the first group of this column, none have the same number on both sides, and the greatest difference is five. The number of specimens in the fourth group of the actual column is 126. Each has 43 scales on the right side, and on the left three have 41, fifteen 42, fifty-six 43, thirty-seven 44, thirteen 45 and two 46. The largest number of individuals in this group which have the same combination, have the same number of scales on both sides, and the greatest difference in the number on the two sides as in the other cases is three. The calculated column of the same group contains 125 specimens, each of which has 43 scales on the right side. On the left side, two have 41, eleven have 42, thirty-four 43, forty-two 44, twenty-three 45, ten 46, two 47 and one 48. The largest number in this case with the same combination has 43 scales on the right side and 44 on the left, and the greatest difference, as before, is five.

The number of specimens in the same groups of the two columns is the same in most cases, and in no case is there a difference of more than one. This difference is perhaps due to the dropping and adding of fractions. In the calculations fractions of less value than one-half were dropped and those of a value of one-half or more were called one. It will be observed from the groups described—and the same is true of the other groups—that when the number of scales is the same on each side or not more than a difference of one, the actual column exceeds the calculated, and as the difference increases, the calculated column exceeds the actual. A comparison of the corresponding groups in the two columns in every case gives the same results as in those described, all of which demonstrates the tendency to bilateral symmetry or a marked correlation in the variation of the two sides.

Preliminary Note Upon the Arrangement of Rods and Cones in the Retina of Fishes. By C. H. Eigenmann and George Hansell.

[Abstract.]

A variety of fish eyes were examined, and it was found that in most cases the rods and cones are arranged in a regular pattern. This pattern is either that described by Hannover and Ryder for fishes or a slight modification of this pattern.

Degeneration in the Eyes of the Amblyopsidæ, Its Plan, Process and Causes. By Carl H. Eigenmann.

[Summary only.]

1. There are at least six species of "blind fishes," Amblyopsidæ, inhabiting North America, three with well-developed eyes and three with mere vestiges.

2. The three species with vestigial eyes are descended from generically distinct ancestors with well-developed eyes.

3. These species can be more readily distinguished by the structure of their eyes than by any other characteristic.

4. The most highly-developed eye is much smaller and simpler than the eye of normal-eyed fishes.

5. The structure of their eyes may be represented by the following key to the genera and species.

a. Vitreous body and lens normal, the eye functional. No scleral cartilages. Eye permanently connected with the brain by the optic nerve. Eye muscles normal. No optic fibre layer. Minimum diameter of the eye .700 μ.

Chologaster.

b. Eye in adult more than 1 mm. in longitudinal diameter. Lens over .5 mm. in diameter. Retina very simple, its maximum thickness 835 μ in the old; the outer and inner nuclear layers consisting of a single series of cells each; the ganglionic layer of isolated cells. Maximum thickness of the outer nuclear layer 5 μ; of the inner layer 8 μ .... cornutus

bb. Eye in adult less than 1 mm. in longitudinal diameter. Lens less than .4 mm. Outer nuclear layer composed of at least two layers of cells; the inner nuclear layer of at least three layers of cells, the former at least 10 μ thick, the latter at least 18 μ.

c. Pigment epithelium 65 μ thick in the middle-aged, 102 in the old. papilliferus.

cc. Pigment 49 μ thick in the middle-aged, 74 in the old; 24–30 per cent. thinner than in papilliferus. Eye smaller .... agassizii.

aa. The eye a vestige, not functional; vitreous body and lens mere vestiges; the eye collapsed, the inner faces of the retina in contact; maximum diameter of eye about 200 μ.

d. No scleral cartilages; no pigment in the pigment epithelium, a minute vitreal cavity; hyaloid membrane with blood vessels. Pupil not closed. Outer nuclear, outer reticular, inner nuclear, inner reticular, ganglionic and pigment epithelial layers differentiated. Cones probably none. No eye muscles. Maximum diameter of eye 180 μ. Eye probably connected with brain throughout life .... Typhlichthys.

dd. Scleral cartilages; pigment in the pigment epithelium; vitreal cavity obliterated; no hyaloid membrane. Pupil closed. Some of the eye muscles developed. No outer reticular layer. Outer and inner nuclear layers merged into one. Eye in adult not connected with the brain.

e. Pigment epithelium well developed; cones well developed; ganglionic cells forming a funnel-shaped mass through the center of the eye. Pigmental epithelium over the front of the eye without pigment. Maximum diameter of eye about 200 μ .... Amblyopsis.

ee. Pigment epithelium developed on distal face of the eye, rarely over the sides and back. No cones. Nuclear layers mere vestiges; the ganglionic layer restricted to the anterior face of the eye just within the pigmented epithelium. Maximum diameter of the eye about 85 μ .... Troglichthys.

6. The structure of the vestigial eyes differs much in different individuals.

7. The eye of Chologaster is an eye symmetrically reduced from a larger normal fish eye.

8. The retina in Chologaster is the first structure that was simplified.

9. Later the lens, and especially the vitreous body, degenerated more rapidly than the retina.

10. The eye of Typhlichthys has degenerated along a different line from that of Amblyopsis, its pigmented epithelium having been most profoundly affected.

11. The eye muscles have disappeared in Typhlichthys.

12. Troglichthys shows that the steps in the degeneration of the muscles were in the direction of lengthening their attaching tendons, finally replacing the muscles with strands of connective fibres.

13. The scleral cartilages have not kept pace in their degeneration with the active structures of the eye.

14. The lens in the blind species is, for the most part, a small group of cells without fibres.

15. The proportional degeneration of the layers of the retina is shown in diagram j.

16. With advancing age the eye of Amblyopsis undergoes a distinct ontogenic degeneration from the mature structure.

17. The phyletic degeneration does not follow the reverse order of development. None of the adult degenerate eyes resemble stages of past (phyletic) adult conditions.

18. The degenerate eyes do not owe their structure to a cessation of development at any past ontogenic stage, *i. e.*, at any stage passed through in the development of a normal life.

19. Cessation in development occurs only in the reduction of the number of cell generations produced to form the eye not in cessation of morphogenic processes.

20. In some cases (Typhlichthys) there is a retardation in the rate of development, the permanent condition being reached later in life than is usual in fishes. (It is possible that the pigment of the pigment epithelium never comes to develop at all. It is, however, impossible to assert this until the embryos of this species are examined. It is possible that the pigment degenerates before the stages are reached that I have examined.)

21. The degenerate condition of the eye appears in the embryo. The crowding back has followed the law of tachygenesis.

22. The conditions in the eyes of the Amblyopsidæ can only be explained as the result of the transmission of disuse effect.

The Ear and Hearing of the Blind-fishes.* By Carl H. Eigenmann and Albert C. Yoder.

The following words of Prof. Cope are frequently quoted: "They (Amblyopsis) are unconscious of the presence of an enemy, except through the medium of hearing. This sense, however, is evidently very acute; for at any noise they turn suddenly downward and hide beneath stones, etc., on the bottom."

Miss Hoppin (Garman, 1889) was the first to cast doubt on this statement. She failed to get any response from Troglichthys as long as noises only were resorted to.

Our own observations (Proc. Brit. Ass. A. Science, Toronto Meeting) on Amblyopsis confirm those of Miss Hoppin on Troglichthys. No noises produced had any effect on Amblyopsis. Whistles, tuning forks, clapping of hands, shouting in the reverberating caves, were alike disregarded. Not one observation was made that would indicate that these fishes can hear. This does not imply that the auditory organs of this fish are not fully developed. Nor is it an indication that the auditory function of this fish is degenerate, for Kreidl and Lee have both shown that fishes as a class are unable to hear. Kreidl's observations were made on fishes which were blinded or from which the operator was hidden by some contrivance. Neither of these devices need be resorted to with the present species.

Anatomically considered, the ear of Amblyopsis is normal. Numbers of ears together with the brains have been dissected out. These were treated either with Flemming's strong solution or with Hermann's fluid, either of which stained the nerve matter black.

In the first place, the three semi-circular canals are present and each has its ampulla fully developed. The three ampullæ and the sinus utriculus superior communicate with the utriculus in front, behind, and above Below, the utriculus communicates with the sacculus, which terminates posteriorly in an appendage, the lagena.

The three ear bones are present, one in the recessus utriculi, one (the largest) in the sacculus, and the other in the lagena.

The auditory nerve divides into two branches, the ramus anterior and the ramus posterior. The ramus anterior divides into three branches—the ramulus ampullæ anterioris, which extends to the anterior ampulla;

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*Contributions from the Zoölogical Laboratory of the Indiana University, No. 30.

the ramulus ampullæ externæ, which extends to the external ampulla; the ramulus recessus utriculi, which extends to the recessus utriculi. The ramus posterior gives off a heavy branch, the ramulus sacculi, which extends to the sacculus. The rest of the ramus posterior divides into the ramulus lagenæ, which extends to the lagena; and the ramulus ampulla posterioris, which extends to the posterior ampulla. Another branch, the ramulus neglectus, which is normally given off where the ramus posterior divides into the ramulus ampulla posterioris and ramulus lagenæ, has not been identified.

The normal fish ear has seven auditory spots—the macula acusticus recessus utriculi, three cristæ acusticus ampullarum, macula acusticus cacculi, papilla acusticus lagenæ, and the macula acusticus neglecta. In Amblyopsis all of these auditory spots are present:

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EXPLANATION OF FIGURES.

The lettering is uniform throughout and in the main that used by Retzius in "Das Gehörorgan der Wirbelthiere."

ca—Canalis anterior.

ce—Canalis externus.

cp—Canalis posterior.

s—Sacculus.

u—Utriculus.

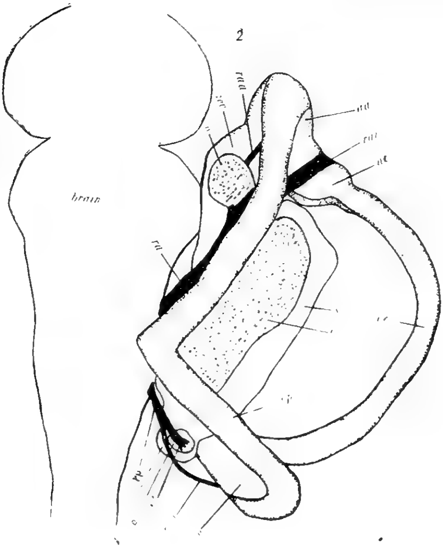
rec—Recessus utriculi.

ss—Sinus utriculi superior.

cus—Canalis utriculo-saccularis.

l—Lagena.

2



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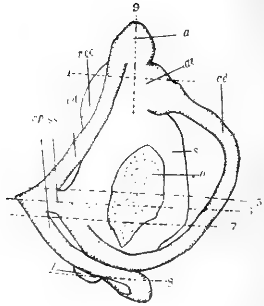

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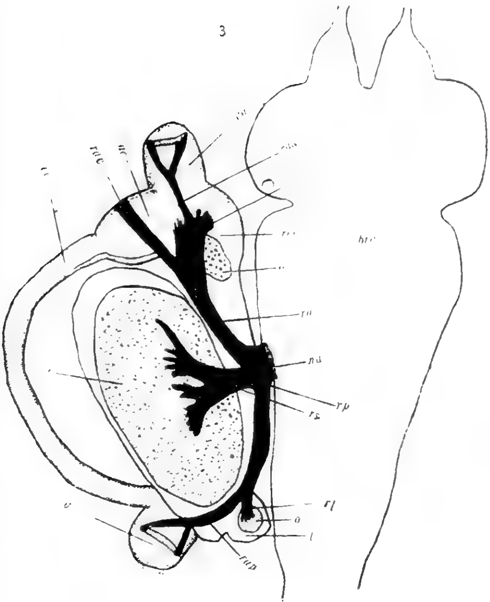

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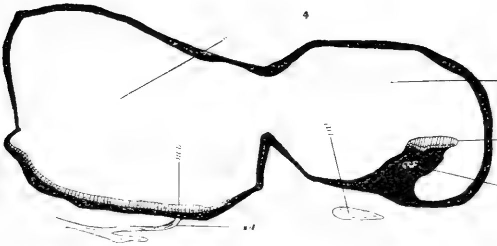

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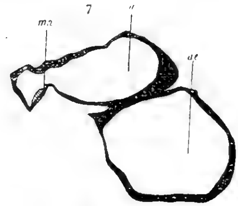

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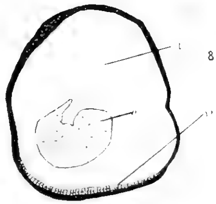

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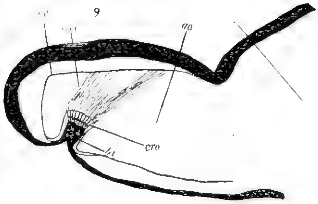


J. de Winter del.

aa—Ampulla anterior.
ae—Ampulla externa.
ap—Ampulla posterior.
cra—Crista acustica ampullæ anterioris.
cre—Crista acustica ampullæ externæ..
mu—Macula acustica recessus utriculi.
ms—Macula acustica sacculi.
pl—Papilla acustica lagenæ.
mn—Macula acustica neglecta.
na—Nervus acusticus.
ra—Ramus anterior.
rp—Ramus posterior.
raa—Ramulus ampullæ anterioris.
rae—Ramulus ampullæ externæ.
rs—Ramulus sacculi.
rl—Ramulus lagenæ.
rap—Ramulus ampullæ posterioris.
ov—Oval opening into sacculus from the canalis utriculi-saccularis.
bv—Blood-vessel.
cap—Capula terminalis.
ep—Epithelial lining.
g—Ganglion cells.
o—Otolith.

Fig. 1. Right ear. Viewed from the exterior and above. The dotted lines show the planes of sections. ×12.

Fig. 2. Brain and right ear. Dorsal view. The nerves are shown black. The fibers for the most part are under the ear, but they were seen through the membranous parts. ×21.

Fig. 3. Brain and right ear. Ventral view. ×23.

Fig. 4. Cross section of utriculus and the crista in the external canal. ×195.

Fig. 5. Part of a vertical section through the brain, ramulus sacculi, and sacculi. The course of the ramulus sacculi is shown here. ×195.

Fig. 6. Section showing canalis utriculo-saccularis and the oval opening through which there is communication between the utriculus and the sacculus. The sections were made parallel to the sinus utriculo-superior. ×195.

Fig. 7. Utriculus and canalis externus. Cross section showing the macula neglecta. ×195.

Fig. 8. Lagena. Cross section showing the capilla acustica. ×195.

Fig. 9. Ampulla anterior. Longitudinal section. Cross section of crista. ×195.

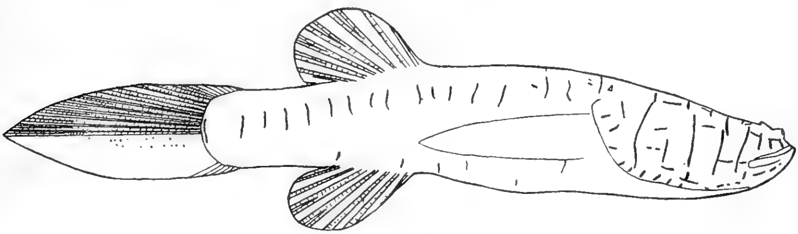
Fig. 10. Utriculus. Cross section showing the macula neglecta. ×(1/6 obj. 2 in oc).

Fig. 11. The three otoliths drawn to the same magnification. The largest belongs to the sacculus; the smallest to the lagena, and the other to the recessus utriculi. ×23.

A Case of Convergence.* By Carl H. Eigenmann.

In 1859 Girard (Proc. Acad. Nat. Sc., Phila., p. 62) described a small blind fish, *Typhlichthys subterraneus* from Bowling Green, Ky. This species has since been found to be abundant in the subterranean waters east of the Mississippi and south of the Ohio.

In 1889 Garman (Bull. Mus. Comp. Zool. XVII, No. 6) gave an account of a blind fish from some caves in Missouri. Mr. Garman says: "Compared with specimens from Kentucky and Tennessee, they agree so exactly as to raise the question whether the species was not originated in



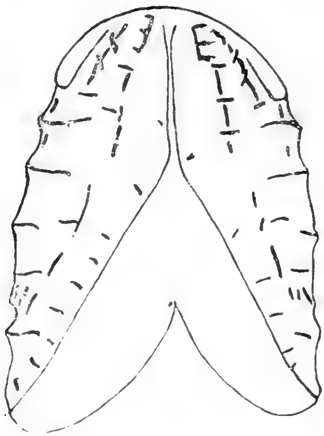
one of the localities and thence distributed to the others. * * * There is no doubt that the representatives of *Typhlichthys subterraneus* in the various caves were derived from a single common ancestral species. The doubts concern only the probability of the existence of three or more lines

*Contributions from the Zoölogical Department of the Indiana University, No. 27.

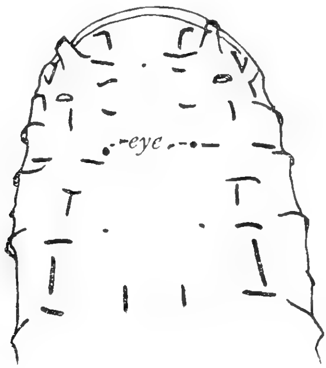
of development in as many different locations, starting from the same species and leading to such practical identity of result."

Ably arguing the case from the data on hand, Garman came to the conclusion "that these blind fishes originated in a particular locality, and have been and are being distributed among the caves throughout the valley" (of the Mississippi).

Two of the specimens from Missouri served Kohl ("Rudimentäre Wirbelthieraugen," 1892) for his account of the eyes of North American



blind fishes. At my request Mr. Garman sent me two of the Missouri specimens. He urged me at the same time to make a more extensive comparison between them and the Mammoth cave specimens. A comparison of the eyes of specimens from the two localities not only proved that they represented distinct species, but that they are of separate origin. An announcement of the species without further description was published (Proc. Ind. Acad. Sci. for 1897, p. 231, 1898). The species was "named *rosæ* for the rediscoverer of the California *Typhlogobius*, a pioneer in the study of biology among women, Mrs. Rosa Smith Eigenmann." In the spring of 1897 I visited various caves in Missouri to secure additional material of what was recognized as in many ways the most interesting member of the North American fauna. No specimens were secured, but a liberal number of bottles of alcohol and formalin were scattered over the country. During this fall, through a grant from the Elizabeth Thompson Science Fund and through the courtesy of the officers of the Monon, the L. E. and St. L. and the Frisco R. R. lines, I was enabled to visit the cave region of Missouri again. This time I visited nine caves and secured eight specimens. I have since received an additional number from a correspondent. From information gathered it would seem that this species (or similar ones) has a wide distribution in the subterranean water of the southern half of Missouri and northern Arkansas, probably also the eastern part of Kansas.



On the surface the specimens very cosely resemble *Typhlichthys subterraneus* from Mammoth Cave, differing slightly in the proportion and in the pectoral and caudal fins. These fins are longer in *rosæ*. It is, however, quite evident from a study of their eyes that we have to deal here with a case of convergence of two very distinct forms. They have converged because of the similarity of their environment and especially owing to the absence of those elements in their environment that lead to external protective adaptations. The details of the structure of the eyes of all the members of the Amblyopsidæ will be published shortly, and I need call attention here only to the structures that warrant the conclusion that the cis and transmississippi forms of blind fishes without ventral fins are of distinct origin. The blind fish *Amblyopsis* may be left out of consideration, since it is the only member of the family that possesses ventral fins. Otherwise, it would be difficult to distinguish specimens of similar size of this species from either *subterraneus* or *rosæ*.

The eye of *T. subterraneus* is surrounded by a very thin layer of tissue representing the sclera and choroid. The two layers are not separable. In this respect it approaches the condition in the epigean-eyed member of the family *Chologaster*. For other reasons that need not be given here, it is quite certain that *Typhlichthys* is the descendant of a *Chologaster*. The intensity of coloration and the structure of the eye are the chief points of difference. The eye of *rosæ* is but about one-third the diameter of that of *subterraneus*, measuring .06 mm. or thereabout. It is the most degenerate as distinguished from undeveloped vertebrate eye. The point of importance in the present instance is the presence of comparatively enormous scleral cartilages.* These have not degenerated in proportion to the degeneration of the eye and in some cases are several times as long as the eye, projecting far beyond it or are puckered to make their disproportionate size fit the vanishing eye. The species is unquestionably descended from a species with well-developed scleral cartilages, for it is not conceivable that the sclera as found in *Chologaster* could, by any freak or chance, give rise during degeneration to scleral cartilages, and if it did, they would not develop several sizes too large for the eye. At present no known epigean species of the Amblyopsidæ possesses scleral cartilages. The ancestry of *rosæ* is hence known. *Amblyopsis* possesses scleral cartilages and the eye of *rosæ* passed through a condition similar to that possessed by *Amblyopsis*, but the latter species has ventral fins and is hence ruled out as a possible ancestor of *rosæ*. The epigean ancestry of *Amblyopsis* is also unknown. The ancestry of *Typhlichthys* being quite distinct from that of *rosæ*, the latter species may be referred to a new generis named *Troglichthys*.

Judging from the degree of degeneration of the eye *Troglichthys* has lived in caves and done without the use of its eyes longer than any other known vertebrate. (*Ipnops* being a deep-sea form is not considered.) More than this, *rosæ* is probably the oldest resident in the region it inhabits.

Since the specimens kindly sent by Mr. Garman, in the course of examination, have been reduced to sections, the specimens now in my possession, together with a few sent to the British Museum, all having come from the same cave, may be considered typical.

In addition to the acknowledgments made before I wish also to thank the officers of the Louisville and Nashville R. R. for transportation to Mammoth Cave. I must especially express my appreciation of the assist-

* Kohl mistook the nature of these structures, as he did of every other connected with these eyes, except the lens and ganglionic cells.

ance rendered me by Mr. William McDoel, General Manager of the Monon, in enabling me to make explorations in the numerous caves of the Lost River region along his line and to visit caves at greater distances. Mr. H. C. Ganter, the manager of the Mammoth Cave Hotel, not only granted me leave to collect in the cave, but did everything possible to make my trip to this cave successful.

Chologaster agassizii and Its Eyes. By Carl H. Eigenmann.

[Abstract.]

Chologaster agassizii has heretofore been known from the type specimen only. This came from a well at Lebanon, Tennessee. I have heard of other specimens, but neither persuasion nor a liberal cash promise was able to bring one of these specimens. Five specimens were recently caught by me.

Chologaster agassizii possesses this peculiar interest: The Amblyopsidæ, evidently the wreck of an ancient numerous family, are now represented by Chologaster with well-developed eyes, and the various blind fishes with greatly degenerate eyes. Of Chologaster there are three known species. One of these lives in the streams of the Atlantic slope and does not concern us. The other, Ch. papilliferus, lives in springs in southwestern Illinois, while the third, Ch. agassizii, lives altogether in subterranean streams. I wanted Ch. agassizii to compare its eyes with those of Ch. papilliferus. The interest is heightened by the fact that the two species are very similar, the eye of agassizii is, however, very much smaller and will, when examined, give us one of the steps of degeneration through which this structure passes.

The Eye of Typhlomolge from the Artesian Wells of San Marcos, Texas. By C. H. Eigenmann.

[Abstract.]

The eye of Typhlomolge has lost the lens and for the most part the vitreous body. The eye has, as a result,collapsed. The pupil is still open in the young but becomes closed in the adult, and in its region the pigment of the iris becomes much thicker than the pigmented layer at the back of the retina.

The Eyes of Typhlotriton Spelæus.* By Carl H. Eigenmann and W. A. Denny.

[Abstract.]

Typhlotriton was discovered in Rock House Cave, Barrie County, Mo., by Mr. F. A. Sampson, in July, 1891. The specimen was described by Stejneger in the Proc. U. S. Nat. Mus., Vol. XV, p. 115. This is the only mention made of this salamander in literature.

In the spring of 1897, I visited Rock House Cave and secured a number of larvae which Stejneger pronounced the larvae of his Typhlotriton. I was informed by Mr. E. A. Schultze, a member of this academy, that he had seen this salamander in the underground passage to Blondis Throne room in Marble Cave, Mo.

In September of 1898 I visited this cave and secured four adults and three larvae of the Typhlotriton. A large number of larvae were obtained from Rock House Cave. Those from Rock House Cave had lived in the light, but it is scarcely supposable that those from Marble Cave had ever been affected by the light. In the caves both larvae and adults are found under stones in and out of the water. Occasionally one is seen lying on the bottom of a pool.

In the aquarium the larvae creep into or under anything available. A rubber tube served as a hiding place. The rubber tube admitting water to the acquarium is sometimes occupied by several (at one time seven) during a temporary cessation of the flow of water. A wire screen sloping from the bottom of the aquarium forms the most popular collecting place of the larvae. They collect beneath this, although it is no protection from the light. The eye does not protrude in the larva but it does in the adult. It is retracted after death, however, so that preserved specimens will not give a correct impression of the real condition.

The following are a series of measurements on the larvae of Typhlotriton.

	Rock House Cave. mm.	*Rock House Cave.* mm.	*Marble Cave.* mm.
Specimen (length)	54	78	88
Size of pupil	.432	.640	.....
Length of eye	1.30	1.50	1.60
From optic nerve to front of lens	.80	1.20	......
Vert cal diameter	.....	1.248	1.28

* Contributions from the Zoölogical Laboratory of the Indiana University, No. 31.

An adult and a larva taken from Marble Cave were sectioned in the usual manner. The lens and iris in both were normal. The only difference in the histological structure of the eye, when compared with the normal salamander (Amblystoma jeffersonianum), is found in the retina.

In the larvae all the layers of the retina are well developed. The ganglionic layer is much thicker than that of the Amblystoma, having many rows of cells instead of one or two. All the other layers are normally present, the rod and cone layer being well developed. The retina in the larva is much thicker than in the adult. In the adult the rods and cones have disappeared, there being only an occasional process from the outer nuclei.

In all the sections thus far studied we have been unable to detect the slightest indication of an outer molecular layer in the adult, while in the larva this layer is normally developed. The ganglionic layer is thicker in the larva than in the adult. In this respect the adult approaches the normal more than the larva does. The Müllerian fibres are profusely present in both larva and adult.

SUMMARY.

1. The larval retina approaches the normal (Amblystoma) more than the adult. The only apparent difference is a thickening of the ganglionic layer.
2. The retina is thicker in larva than in adult.
3. All the layers are present in the retina of the larva, while in the adult the rods and cones and the outer molecular layer have not been made out; the inner molecular layer is thinner.
4. The ganglionic layer is thicker in larvae than in adult.

The Blind Rat of Mammoth Cave.* By Carl H. Eigenmann and James Rollin Slonaker.

Habits and Habitat, by Carl H. Eigenmann. No. 32.

In his origin of species, sixth edition, Vol. I, page 171, Darwin says that the eyes of Neotoma of Mammoth Cave are "lustrous and of large size; and these animals, as I am informed by Prof. Silliman, after having been exposed for about a month to a graduated light, acquired a dim per-

*Contribution from the Zoölogical Laboratory of the Indiana University.

ception of objects." The cave rat, Neotoma, is still abundant in Mammoth Cave. It is found in the rotunda near the entrance of the cave and in the more distant parts of the cave. Its tracks are numerous, and in places little paths have been made by the rats where they run backward and forward along ledges of rock. Since, however, a track once made in a cave remains unchanged by wind or weather, the abundance of rats, as judged by their tracks, may be misleading. A number of traps were set in the rotunda. During three days one trap was sprung and one had the bait removed. No rats were caught in the traps and none were caught alive. I discovered one rat rolling a mouse trap about which was too small for it to enter. When approached with a light the rat turned about

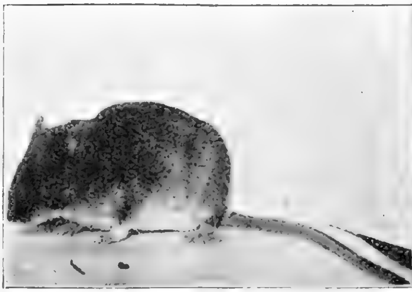


Fig. 1. Mammoth Cave Rat.

Fig. 2. Common Gray Rat.

and stared at the light. It then ran to a pile of rocks but did not attempt to hide; instead the rat ran to one end of the pile, then along the top back to where I stood, when it stopped and again stared at the light. An attempt to catch the rat sent it running back and forth along the ledges of rock at the side of the cave. Finally the rat came to the ground again, and despairing of catching it alive it was killed. Its eyes appeared to be large and protruding very much as in the common rat. Without question the rat noticed the light. It had no hesitation in running from place to place. The manager of the Mammoth Cave Hotel, Mr. H. C. Ganter, later caught four rats which he sent by express. Only one arrived alive; one had been partly eaten by the others. The living one is now caged. It is quite gentle. It permits itself to be stroked. Occasionally it pushes an object away with a sideward motion of the fore foot. If provoked it snaps at the object. During the daylight it sits quietly in a nest it has formed for itself of cotton batting, which it pulled into a fluffy mass. At night it is frequently moving about in its cage. Turning on an electric light near its face always produces a twitching of the eyelids; so there can be no doubt that the light is perceived. An object held some distance from the cage either on one side or another is always perceived, but just how precise its vision is has not been determined. Its hearing is acute.

THE EYE. BY J. R. SLONAKER.

As far as I have been able to ascertain, little or no microscopical investigation has been made on the eye of the Mammoth Cave rat.

A glance at a photograph of a cave rat (Fig. 1) shows that the eye is as prominent as in the common gray rat (Fig. 2).

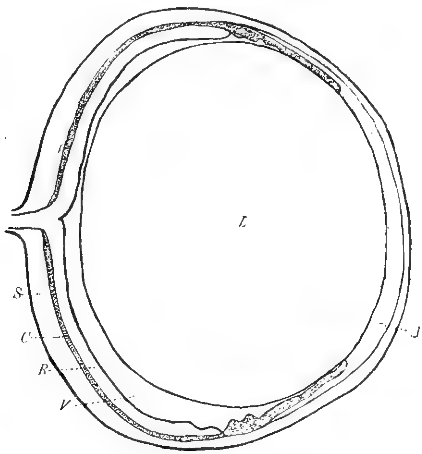


Fig. 3. Mammoth Cave Rat (× 8).

If the elements of the retina have the same function in the cave rat as in other rats, we may approach closely to their power of sight under favorable conditions, by comparing their retina with that of those living in the light. For such a preliminary comparison I have chosen the nearest allied form which I could readily get, the common gray rat (Mus decumanus).

The eye of the cave rat is, if anything, larger in proportion to its body weight than that of our gray rat (Figs. 3 and 4). The lens is in each case enormously large in proportion to the eye, so large, in fact, that very little space is left for the aqueous and vitreous humors. The pupil is capable of very wide dilation, as is true with most nocturnal animals.

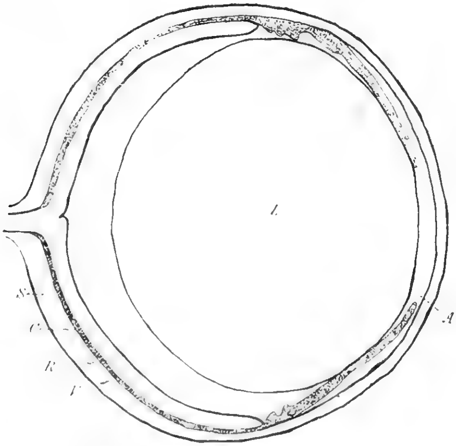


Fig. 4. Common Gray Rat (× 8).

A. Aqueous Chamber.
C. Choroid and Pigment Layers.
L. Lens.
R. Retina.
S. Sclerotic.
V. Vitreous Chamber.

The head of the cave rat, being more rounded and less pointed than that of the gray rat, permits of a slightly deeper eye-socket. However, these two rats resemble each other in their "pop-eyed" appearance when frightened.

A microscopical comparison of the retina also shows little difference. Bits of retina from corresponding parts of the eye of a cave rat and a gray rat were hardened by the same process, sectioned the same thickness and stained alike, so that the sections are directly comparable. Fig. 5 represents semi-diagrammatic camera drawings of two such sections.

At a glance one can see that there is very little difference excepting in the thickness of the retina, that of the cave rat being thicker. This difference, however, may be due to the fact that Fig. 5a, is from a very large cave rat, while Fig. 5b is from a half-grown gray rat. The thickness, however, bears about the same ratio to the size of the eye in each

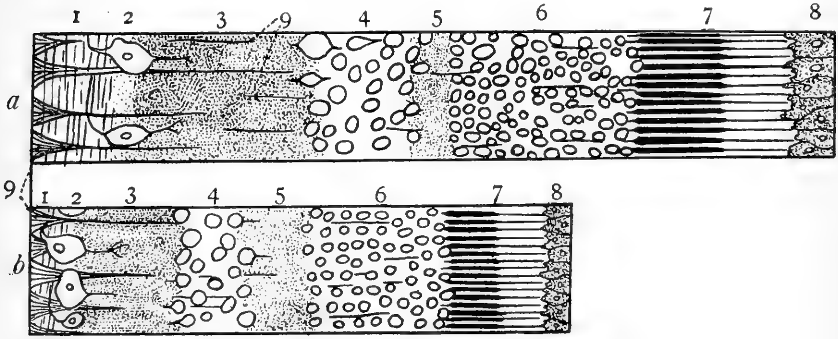


Fig. 5. Semi-diagrammatic camera drawings (× 265).

a. Mammoth Cave Rat.
b. Common Gray Rat.
1. Nerve Fibre Layer.
2. Nerve Cell Layer.
3. Inner Molecular Layer.
4. Inner Nuclear Layer.
5. Outer Molecular Layer.
6. Outer Nuclear Layer.
7. Rod and Cone Layer.
8. Pigment Layer.
9. Supporting Fibres of Müller.

case. This greater thickness is largely due to an increase in the size of the cells of corresponding layers of the retina in the cave rat. Only a single instance need be given. The rod and cone layer of the cave rat is composed of decidedly longer and larger elements than the same layer of the common rat. But with the exceptions of these minor differences in the thickness of the layers and in the size of the cells, the two retinae are nearly alike.

Basing our conclusions on the histological structure of the eye, we may infer that the cave rat has the power of seeing as distinctly as the common gray rat.

A NEMATOID WORM IN AN EGG. BY DANIEL J. TROYER.

THE GEOLOGIC RELATIONS OF SOME ST. LOUIS GROUP CAVES AND SINKHOLES. BY M. N. ELROD, M. D.

Before discussing the geologic relations of the caves, sinkholes and subterranean channels of St. Louis limestone to each other and to the strata in which they occur, it will be necessary to define the limits of that formation in Indiana. The Warsaw bed, as exposed at Spergen Hill and elsewhere, is recognized as the equivalent of the Bedford oölitic limestone, and the lowest member of the St. Louis. The fossils found in it are abundant and characteristic, and its lithologic peculiarities obvious. But the upper limits of the group are not so well settled. When Prof. James Hall first fully defined the Kaskaskia group, as seen on the banks of the Mississippi River, he included as its lowest member a stratum of sandstone. In Indiana the first sandstone stratum above the St. Louis has been recognized as forming a part, at least, of the Kaskaskia group, but not always as its lowest limit. The classification of Prof. Hall* was first applied to the geologic formations of Indiana by ex-State Geologist E. T. Cox, in 1872, in a report on the geology of Perry County,† in which he made the first sandstone above the St. Louis the base of the Kaskaskia group, and by the law of priority, his identification should be recognized unless there is sufficient reason for a change. Since that time the dividing line has been placed at a lower level; one observer finding it at a small coal seam in the limestone strata;‡ others at the top of the upper fossiliferous chert member of the St. Louis;¶ and others have included with the Kaskaskia extensive strata of limestone under the sandstone, without indicating by a section or otherwise where the one terminated and the other began.§ Much of this confusion has grown out of an effort to limit the upper St. Louis group to such strata only as contain *Lithostrotion canadense* Castelnau and *L. proliferum* Hall, characteristic fossils

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* Hall's Geol. of Iowa, pt. 1, p. 109, 1858.

† Geol. Sur. Ind., 1872, pp. 76, 77.

‡ Geol. Sur. Ind., 1873, p. 365; 1878, pp. 305, 425.

¶ Geol. Sur. Ind., 1875, pp. 207, 216.

§ Geol. Sur. Ind. 1895, pp. 231, 232; 1896, p. 300.

of the undisputed St. Louis formations. But if this palæontologic test is to be applied to the upper strata it is hard to understand how the Bedford oölitic can be retained as a member, as these fossils are not found in it.

At the top of the sinkhole division of the St. Louis in Lawrence, Orange and Washington Counties, and doubtless in Harrison County, there is a constant stratum of chert from ten to twenty inches thick. Above this chert other thin flinty layers may be found, but so far as known, they are not fossiliferous. The heavy chert may be seen in place at Paoli in the north bank of Lick Creek, at the Wesley Chapel Gulf, and on Lost River near Orangeville. Because of its frequent occurrence on that stream is is suggested that it be named the Lost River chert. It is generally highly fossiliferous, very rich in bryozoans and occasionally oôlitic. *Above, and conformable with it, there is found from sixty to ninety feet of massive, close-textured limestone, slightly broken at the top by beds of calcareous shale, and near the middle by included chert nodules; generally the ground mass is lithographic. This stratum includes all the rocks found below the first Kaskaskia sandstone and above the Lost River chert, and as it is well exposed at that place it is proposed that it be known as the Paoli limestone. On palæontologic grounds, which cannot be presented in full here, the Paoli limestone is assigned to the St. Louis group. The fossils that occur in it, at many places in abundance, are of the same species as the more common forms found at Spergen Hill. The chemical composition and general appearance is such as to clearly show that it is a repetition of the strata exposed below it. Its lithologic characteristics are obvious, and the residual clay resulting from its disintegration presents the same physical appearance as the red, plastic and impervious clay of the undoubted St. Louis formations.

Mr. C. E. Siebenthal has proposed the name Mitchell limestone for "A series of impure limestones, calcareous shales and fossiliferous limestones" overlying the Bedford oölitic limestone, and says: "The topographic *tendency* of the Mitchell limestone expresses itself in plateaus perforated at short intervals by sinkholes."* As he does not define the upper limits of his "Mitchell limestone" it is suggested that his definition be amended to include all the St. Louis limestone below the Lost River chert and above the Bedford oölitic. Its upper and middle strata are largely

* Geol. Sur. Ind., 1896, pp. 298, 299.

lithographic, and quite often include chert nodules and plates. The upper members are the equivalent of the true "Cavernous limestone," and the "Barrens." In the lower portion sinks are not so common, and the strata become argillaceous and in many places hydraulic.

A section through Orange and Washington counties will show the following succession of formations:

Kaskaskia, sandstone—	
St. Louis.	***Ft.***
Paoli limestone, calcareous shale and lithographic limestone	90
Lost River chert, fossiliferous	1
Mitchell limestone, lithographic limestone and calcareous shale with chert inclusions, the lower portion argillaceous and hydraulic	160
Bedford oölitic limestone—Warsaw	60
Keokuk.	
Total	311

The caves of the impure, lower Mitchell limestone stratum are peculiar in that they are only incidentally connected with surface sinks, and generally have streams of water flowing from the external opening. The mouth is usually found above the oölitic limestone in the side hill of a deep valley. The interior shows the erosive effects of running water, the passage diminishes in size as it recedes from the mouth, and its side branches are low, narrow reproductions of the main cave. To this class belong Donnehue's, Hamer's and Donnelson's caves in Lawrence County, Clifty and some of the caves near Beck's Mill, Washington County, and nearly all those found elsewhere near the eastern limits of the St. Louis group.

Where the clay shales and argillaceous limestones are the surface rocks the country is very much broken by valleys that are quite different from the circular and oval depressions of the sinkhole region proper. Sinks are not wholly absent, but they are not characteristic. At many places the landscape is further modified, and the rock exposure obscured by a mantle of Loess clay that is continuous from East White River, north of Mitchell, over the oölitic and eastern argillaceous limestone area to Salem, and on the east side of Harrison County. West of the Loess belt the lower Mitchell limestone is still the surface stone. Springs are not infrequent, and their waters combine to form small creeks that flow over the exposed edges of the strata until they reach the upper drainage level of the sinkhole area.

Small caves are common over the true cavernous limestone area and clearly show their connection with one or more sinkholes. The best known, and perhaps the largest, example of this class of caves in Orange County is found three miles west of Orleans, on the Peacher farm. Here the roof of the original cave has fallen at some period in the past and made two caves of what was once but one. The mouth of the west cave is large and opens into a wide room that terminates at the other end in a small but characteristic sinkhole. The outer roof of the east cave is low, and it can only be entered by crawling for quite a distance. Once inside, the explorer finds a capacious passage in which the sides below the middle converge to a narrow channel. The walls are covered with mud, and after a heavy rain both caves are filled with muddy water. Such so-called caves are a part of the underground drainage system of the country, and are peculiar in that they are near muddy passages, devoid of stalactites or other features that make caves so interesting to most persons. If it is kept in mind that sinkholes proper are circular basins, whose sides form a gradual slope from the rim to the bottom, they will be readily distinguished from another class where one or more of the sides is a precipitous wall of rock. The first are doubtless due to the slow chemical and mechanical forces that have tunneled the subterranean channel, the latter to the collapse of the roof of a vast cavernous opening whose arch had become weakened by a vertical fissure. At places there is evidence that the roof of the cave has fallen as much as ninety feet. This class of depressions impart to the landscape a peculiar, rugged, broken aspect, and impress the beholder with a feeling that old earth may at any moment slip from under his feet. Occasionally, at each end of the fallen mass, an opening may be found to the cave below. But usually the openings are small and do not appear to be anything more than woodchuck holes, until some winter morning the moist air of the cave, as it rushes out, is touched, as if by fairy fingers, and the shrubbery growing near hung with festoons of hoar frost. The angular depressions are found west of the small circular basins, and near the foot of the Kaskaskia group sandstone hills. Great blocks of Lost River chert cumber the ground in marked contrast to the smaller fragments of the eastern margin of the typical sinkhole limits. It is possible that some of the circular depressions may have been exposed by the roof of a cave falling, but if such was the case there is no evidence of it left. The roof must have been composed of limestone as their rims are several feet below the geologic horizon of the Lost River chert. If limestone fragments of the roof were ever present they have disappeared; and the more probable theory seems to be that the depression is the result of erosive forces acting equally upon all the sides. The rocks exposed in place where the sinkholes are common in Lawrence, Orange, Washington and Harrison counties are always members of the upper or middle portion of the Mitchell limestone, and the angular chert masses and fragments scattered over the surface and mixed with the red residual clay come from the same strata or from the Lost River chert stratum.

The sinkhole area, as a rule, has no surface creeks and branches, and such as reach its limits from without soon find an opening and disappear wholly or in part, except Blue River and Buck Creek. Occasionally the creek or branch is replaced by a dry-bed channel. The dry-beds only come into use after heavy rains or when the subterranean passages are burdened beyond their capacity. Lost River through a part of its surface course is a typical dry bed. When it reaches the eastern edge of the sinkhole region it finds a number of underground channels that take in all the water of the perennial stream east of the Orleans and Paoli road. If the first openings are overtaxed, the overplus of water passes through a dry-bed channel farther west into other sinks, but after an excessive rainfall all the sinks fail, and water runs on the surface through the whole extent of the dry-bed system and again becomes a part of the perennial stream a short distance below the Orangeville "rise." Indian Creek for a part of the year runs underground, but, unlike Lost River, the greater part of its water passes over a surface channel and a dry bed is only exposed during the summer months. It sinks two miles southwest of Corydon and "rises" again five below on an air line, and twice that distance following the meanderings of the creek bed. There is ample evidence that Lost River, like Indian Creek, at some period in the past was wholly, or for the greater part of the year, a surface stream over its dry-bed channel.

Contrary to what might be expected, the subterranean channels do not greatly increase in capacity as they unite and pass under the Kaskaskia

Hills. This is shown four miles west of Orleans at what is called the "wet-weather rise" of the dry-bed. Here water flows out as it is flowing into the upper sinks, hence water may be flowing through two miles of the upper and lower course of the dry bed and not through the middle channel. As soon as the flood-water begins to recede at the "wet-weather rise" the direction of the flow changes, and, instead of running out, flows back into the opening from which it came. At times the whole underground system of channels is overtaxed and the water finds an outlet at many places, and occasionally through artificial openings, such as the well at Brookstown and another east of Orleans.

The underground channel of Lost River can be reached at three places through cavernous openings. At the first of these, near the first sinks, the superincumbent limestone is about forty feet thick; at the second opening the channel is not less than sixty feet below the Lost River chert; at Wesley Chapel Gulf it is thirty feet below the chert stratum, and the same at Orangeville. This indicates that the subterranean channel closely follows the dip of the strata to the west.

Comparatively speaking, sinkholes are rarely seen in the Upper Paoli limestone, and when they do occur are rough, angular openings in the limestone, of limited area. They are not an important feature in the surface drainage of the country, except in the valleys when located near the level of the Lost River chert.

The tendency of the subterranean channels to unite and diminish in capacity gives rise to a number of remarkable artesian springs that burst forth in great volume near the western limits of the Mitchell limestone exposure. The mouth of these springs seems to open into a vertical tunnel in the rock, and is always full of water that ordinarily flows gently away at one side. The deep blue of their water has given rise to the report that they are without bottom. After a heavy rain the volume of water discharged is very greatly increased and shows the effect of increased pressure. They are very unlike the wet-cave springs seen on the eastern limits of the St. Louis group limestone. The Orangeville and Shirley "rises" of Lost River and the Spring Mill head of Lick Creek are examples in Orange County. Those near Hardinsburg, Washington County, and the Harrison Spring and Blue Spouter, in Harrison County, are others of note.

Wyandotte and Marengo Caves belong to a class of caverns noted for their extent and great beauty. They do not seem to occupy a much higher place in the St. Louis series of rocks than the sinkhole channels, but unlike them they are never inundated with floods of muddy water. Their exemption from overflows is due to the fact that the water-bearing channels terminate as artesian springs soon after they pass beyond the sinkhole plateau and under the Paoli limestone and foothills of the Kaskaskia sandstone. The artesian springs are found east of the Crawford County caves, and, if this was not the case, the deep valley of Blue River as it runs south on the eastern boundary of the county, would terminate the westward trend of the underground drainage system of Harrison County. The entrance to the Wyandotte cave is 150 feet above Blue River; and none of the cave entrances of this class are below or on a level with the creeks of the surrounding country, as they are where sinkholes are common. Where the Mitchell limestone is well protected by the overlying Paoli limestone and Kaskaskia strata, caves of any kind are rare, but when they do occur they are very interesting and should be thoroughly explored.

In Missouri, it is said that when the coal measures strata rest immediately on the St. Louis limestone, deep borings pass through cavernous openings,* which is explained by the theory that the St. Louis was for a time dry land and more or less tunneled before the coal strata were deposited.† There is very little data to show that the Indiana St. Louis is cavernous for any great distance beyond the surface sinks. As the sinks are only common where the Paoli limestone has been removed it is reasonable to suppose they do not occur under other conditions, and this view is confirmed by what has before been stated. Two deep wells have been drilled at Paoli and no caverns noted. At Orleans, in one out of three wells, the drill passed through a cave at one hundred feet below the surface; but the latter town is located on the cavernous limestone and the former is not.

In comparing the caves of Indiana with those of Kentucky it is well to remember that in the immediate vicinity of Mammoth Cave, according to competent authority, the Kaskaskia group strata are wanting, and the capping stone of the St. Louis is one of the sandstone members of the lower coal measures. Some of the Kentucky caves are said to reach up to the sandstone, but if the same is true of the Indiana caves the fact has not been noted, nor is it probable that such will be found to be the case.

* Keyes' Mo. Geol Sur. XI, p. 252.

† Keyes' Mo. Geol. Sur. IV, p. 73.

The chemic composition gives a hint as to the origin of the St. Louis caves, and bears out the conclusions here presented. Prof. John R. Proctor says* that in the vicinity of Mammoth Cave the subcarboniferous limestone is "a massive, remarkably homogeneous rock with no intervening strata of shale or sandstone, conditions most favorable for the formation of caverns." In the main his statement is true of the equivalent strata in Indiana, but does not take into consideration certain beds of limestone that weather to a calcareous shale or the variable chemical structure of the Indiana stone, both important elements in studying the relations of the strata to the caves they bear. Probably more to the point is the statement of Prof. W. H. Wheeler,† who, in writing of the topography of St. Louis County, Missouri, says: "The limestones of the St. Louis area are very hard, tough, and resist mechanical disintegration, but on account of the prevalent *purity*, they are very susceptible to chemical dissolution." "If the upper portion of the limestone is impure, and especially if high in magnesia, it is much more resistent to chemical dissolution, and the sinkhole method of drainage is frequently absent. In this case the drainage is by surface channels, which are abrupt and irregular and vary sharply from gentle to heavy slopes." But, while it is conceded that homogeneity and purity largely determine whether the dissolution is chemical or mechanical, they do not appear to fulfill all the required conditions. The Bedford oölitic and Paoli limestones, by chemical analyses, are shown to be from 95 to 98 per cent. calcium carbonate, and the Mitchell limestone less rich in lime by 10 per cent., yet the first two formations have but few caves, while the last is undermined with cavernous openings. That the surface exposure of the Mitchell limestone contributes greatly to its disintegration has already been mentioned, but this does not explain its inherent susceptibility to chemical dissolution. If the number of analyses of the St. Louis limestones above the Bedford oölitic are not near so many as one would wish, those which are available seem to be suggestive. Dr. G. M. Levette, under direction of Prof. E. T. Cox, made a number of analyses of hydraulic cement rock from the lower Mitchell limestone strata of Harrison County, and as equivalent beds of cement rock are found at Becks Mill, Clifty, and many other places, one of them is here given.*

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*The Century Magazine, March, 1898, p. 643.

†Keyes' Mo. Geol. Sur. XI, p. 249.

*Geol. Sur. Ind., 1878, p. 75.

No. 1.—Cedar Grove cement rock.

Water expelled at 212° F	1.00
Insoluble silicates	27.70
Soluble silica	.10
Ferric oxide and alumina	4.00
Lime	35.00
Magnesia	trace
Carbonic acid	27.50
Sulphuric acid	trace
Organic matter, undetermined and loss	4.70
	100.00

The following analyses† were made by Mr. G. A. Kerr for this paper:

No. II.—Bluish-gray, hard limestone with chert inclusions; two miles east of Orleans on the Livonia road. Below the Lost River chert. Specific gravity, 2.68.

Insoluble silica	10.670
Iron	0.304
Magnesia	.461
Alumina	3.210
Calcium carbonate	84.920
Undetermined	.435
	100.000

No. III.—Gray, weathered, friable limestone, from the surface of a bluish-gray, lithographic limestone, one mile west of Union Church and three miles southwest of Orleans. Below the Lost River chert. Specific gravity, 2.44.

Silica, insoluble	5.580
Iron	0.257
Magnesia	0.284
Alumina	3.010
Calcium carbonate	89.904
Undetermined	.965
	100.000

† Thanks are due Mr. G. A. Kerr, chemist to the W. W. Mooney & Son's tannery company, Columbus, Indiana, for kindly making analyses Nos. 2, 3 and 4 at my request.

No. IV.—Drab, fine-grained lithographic limestone. Wesley Chapel Gulf, three miles east of Orangeville. Fifty feet above the Lost River chert near the middle of the Paoli limestone.

Silica, insoluble	1.520
Iron, ferric oxide	.278
Magnesia	.712
Alumina	1.555
Calcium carbonate	95.001
Water expelled at 110° C.	.630
Undetermined and loss	.304
	100.000

One of the first things to be noted in the Mitchell limestone analyses is the persistent presence of a much larger per cent. of silica than is common to an otherwise pure limestone; and it is at least singular that the quantity of silica should be reduced one-half in the weathered specimen from the same horizon. To test whether the less percentage of silica in specimen No. 3 might not be due to a difference in the chemical composition of the unweathered stone from which it was taken, the soft, gray, broken-down surface of No. 2 was tested, and found to contain but 4.82 per cent. of silica as against the 10.67 per cent. of the unweathered mass. The silica from all the analyses was disengaged as an impalpable powder, and it is singular that the insoluble silica should be the first one of the salts to disappear in the process of dissolution. Another fact of note is the constant presence of alumina and a small quantity of magnesia. The low percentage of magnesia doubtless explains why the Mitchell limestones are so readily disintegrated by carbon dioxide in solution.

SUMMARY.

The caves of the St. Louis group in Indiana may be divided into three classes: The wet caves of the lower and more impure Mitchell limestone; the subterranean channels, caves and sinkholes of the middle and upper Mitchell limestone, and those of the upper Mitchell and Paoli limestone. And as to origin: Those in which mechanical forces were dominant; those in which the mechanical and chemical action was nearly equal, and those in which chemical dissolution was the principal factor.

JUG ROCK. BY CHAS. R. DRYER.

Jug Rock is a sandstone pillar forty-five feet high, capped with conglomerate, standing alone upon the slope of a ridge or bluff of White River near Shoals, Ind. It is almost exactly similar in form and material to the monuments in Monument Park, Col. (Photographs and specimens

JUG ROCK.

from both were shown). In Monument Park there are a hundred similar forms; in Indiana but one. The most remarkable thing about Jug Rock is its uniqueness. How conditions could have been adequate to produce one such pillar and did not produce more than one is a puzzle. At other points along White River, as at "the Pinnacle" and "Pike's Rest," some tendency to the formation of similar phenomena is shown.

Pike's Rest.

The Pinnacle.

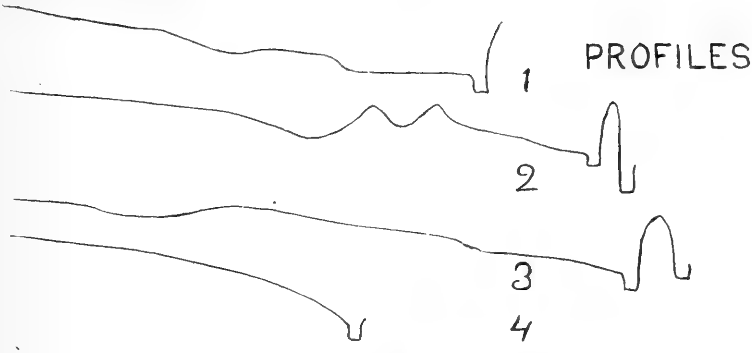
The St. Joseph and the Kankakee at South Bend. By Chas. R. Dryer.

The Meanders of the Muscatatuck at Vernon, Indiana. By Chas. R. Dryer.

At Vernon, Ind., the Muscatatuck River presents a remarkable group of meanders. In a course of six miles it forms four loops, enclosing four tongues of land which are connected with the mainland by very narrow necks. The distance in a straight line from the upper end of the first loop to the lower end of the fourth is less than a mile and a half, and the perpendicular fall about fifty feet. The general level of the upland on both sides of the valley is about 750 feet; the level of the river varies from 630 to 580 feet. Three of the enclosed tongues slope quite regularly from neck to point. Tongue No. 1 is crossed at about its middle by a twenty-foot terrace, below which the surface is at a uniform level of 655 feet, corresponding with the top of the hard Niagara limestone. The tip of the point is alluvial deposit. Tongue No. 2 is occupied by the town of Vernon, and differs from the rest in that the surface slopes from a high and narrow neck rapidly to the 660-foot level, then rises in a double-peaked hill to 715 feet, then slopes gradually to a broad point near the 655-foot level. Tongue No. 3 has a neck only 300 feet wide at the bottom and about ninety feet high. The body of it is about one-fourth of a mile wide and one mile long with a very uniform slope. There is a slight terrace at the 670-foot level, a decided flattening at 650 feet and a rather broad alluvial tip. Tongue No. 4 is the smallest of the group and has the steepest and most symmetrical slope.

The channel of the Muscatatuck is 200 to 300 feet wide and cut down from twenty to fifty feet into the Niagara limestone, which forms bluffs of corresponding height on both sides of the stream. There is practically no flood plain.

The origin of these meanders is a difficult problem. They are very unlike ordinary flood-plain meanders, in which the tongues of land are flat and but little above stream level. They differ also from upland meanders, in which not only the channel but the whole valley winds, the tongues maintaining a uniformly high level and terminating in a bold headland. These are shown in great perfection by the Osage River of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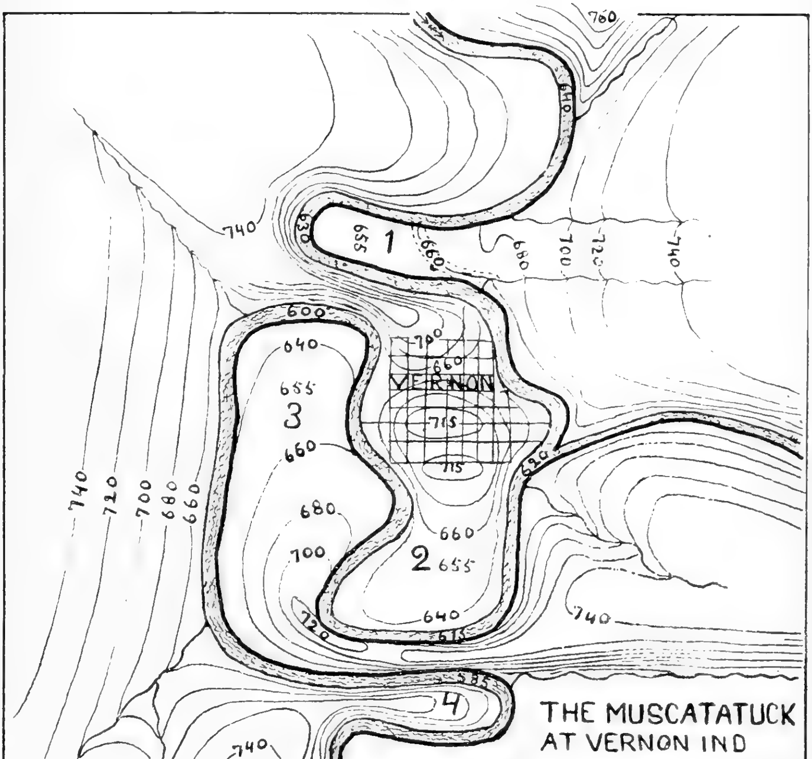

THE MUSCATATUCK
AT VERNON IND
HALF MILE
VERNON
1
2
3
4
740
720
700
680
660
655
640
630
600
715

Missouri. Meanders with sloping tongues, form a class by themselves, and have been most fully discussed by C. F. Marbut of the Missouri Geological Survey.* He publishes maps of the meanders of the Grand and Flat Rivers, but none of them are quite equal to the Vernon tangle of the Muscatatuck.

Two hypotheses have been suggested to account for meanders which are not due to flood-plain conditions. Prof. W. M. Davis has suggested† that they may be superimposed or inherited from a former flood-plain condition. In some previous period the stream has reached base level and developed flood-plain meanders. The basin has been subsequently elevated and the stream in its new cycle has cut its old meanders straight down into the plateau. This may serve to explain meanders in which the tongues are headlands, but evidently will not apply to those of the Muscatatuck, which are not cut straight down.

Winslow‡ thinks such meanders are due to a normal growth and development from an originally crooked consequent course. The germ of the present remarkable loops existed in the slightly irregular surface of the country over which the stream first began to flow. As it corraded its channel more deeply it cut away the convex sides of its bends. It thus became more and more crooked, and by a combination of vertical and lateral corrasion, it slid or sidled down the long slopes of the tongues.

The meanders of the Muscatatuck seem to be better accounted for by development than by inheritance; but the process has been somewhat modified by peculiar conditions. During the cutting of the first seventy or eighty feet, lateral corrasion was more rapid than vertical, and the long gentle slopes of the tongues were formed. At about the 675-foot level vertical corrasion, for some reason, became more rapid and a twenty-foot terrace was formed. At the 655-foot level the stream came down upon the hard and massive Niagara beds, or the corniferous limestone which thinly overlies them. Vertical corrasion seems to have ceased for a long period, during which the stream slid laterally and planed off the broad, flat points of Tongues No. 1 and No. 3. Then came a decided change, probably an elevation of the land and an increase of the slope, which has enabled the stream to cut its channel almost vertically downward into

* Missouri Geological Survey, Vol. X, p. 98.

† Science, Vol. 22, p. 276.

‡ Science, Vol. 23, p. 31.

the Niagara limestone to a depth of from twenty to fifty feet. The small alluvial deposits at the tips of the present tongues show that lateral cutting has not entirely ceased. The hill on Tongue No. 2 may possibly be due to a cut-off formed at about the 660-foot level. The possible course of the stream at about the 670-foot level need not then have been very crooked. Most of its tortuousness has been developed since it struck the Niagara limestone. The nomenclature of the subject is somewhat unsettled. The land enclosed by a meander is called a neck, point or tongue. I propose that the word *tongue* alone be used to designate that feature; that the name *neck* be reserved for the often narrow portion where the tongue joins the mainland, and the name *point* be used only for the tip or extremity of the tongue. In cases where the point is high, as on the Osage River, the term *headland* is natural and descriptive of the whole tongue. For those tongues which slope regularly from an elevated mainland or neck to a low point I propose the analogous term *tailland.*

Taillands are probably not peculiar to the Muscatatuck. I have observed good specimens on Sand Creek at Brewersville and on Laughery Creek at Versailles. The subject is now broached, as far as I am aware, for the first time in Indiana and would probably repay further investigation.

Old Vernon—A Geographical Blunder. By Chas. R. Dryer.

The town of Vernon, the county seat of Jennings County, Indiana, was founded in 1816 at the forks of the Muscatatuck River, which was the head of flat-boat navigation. It is located upon a high, rocky tongue of land, surrounded by the gorge of the river, except at one point, where a neck 130 feet high and just wide enough at the top for a roadway connects it with the mainland. The area enclosed is about one-fourth of a square mile, which is bounded, except at a few points, by perpendicular bluffs from 40 to 90 feet high. It rises at the center in a double-peaked hill 100 feet above the river. As a site for a medieval castle with a cluster of cabins around it, designed primarily for defense, it is unrivaled. It is a Hoosier Ehrenbreitstein. As a site for a modern commercial town it is a failure. In 1850 the Ohio & Mississippi Railroad passed about two miles north of it, and the business center was soon transferred to its station, North Vernon. Other railroads have come to North Vernon since, but on account of engineering difficulties, only one touches Old Vernon, and, by a long fill and double bridge 80 feet high, crosses the river at the forks. The population of North Vernon is 3,000; of Old Vernon, 650. The courthouse and jail seem to be the only reason for its existence, but its quaint and picturesque beauty give it a charm which no smart business town can possess.

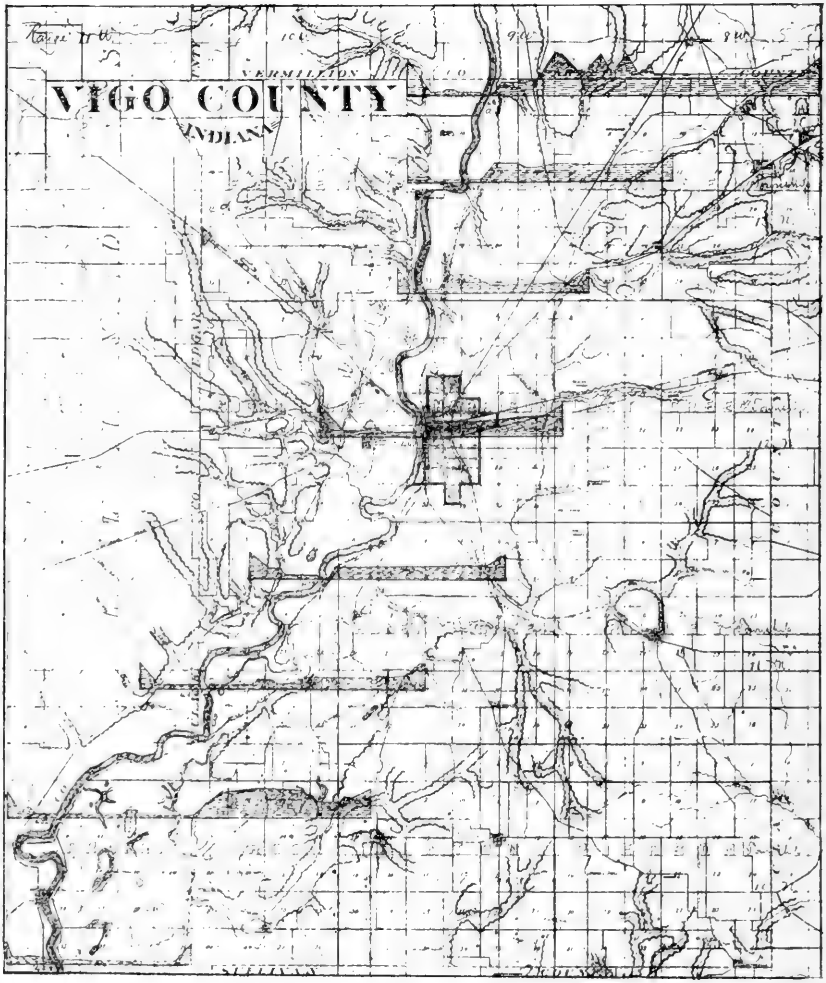
TERRACES OF THE LOWER WABASH. BY J. T. SCOVELL.

The valley of the Wabash, while much like many others, has some peculiarities. It was dug out through the sand and gravel that partially filled an ancient drainage channel. The old channel in Vigo County is from four to six miles wide, and at Terre Haute the bed of the present river is 100 feet above the rock bed of the old river. A long, narrow island whose southern extremity extends a mile or so into Vigo County divided the old river into two channels. The main channel, on the west of the island, now occupied by the Wabash, is about two miles wide. Near the county line it received a tributary channel about one-half mile wide, now occupied by Brouillet's Creek. The eastern channel is about a half mile wide, and is occupied by the lower course of Raccoon Creek. Near the county line this channel received the tributary channel of Old Raccoon Creek, about a half mile wide. Thus the old valley in Vigo County was formed by the union of four broad channels. The flood plains and the terraces of the present river rise to different elevations above low water, and vary considerably in width. Some of these variations are shown by cross sections of the valley made on different lines along its course.

The first section is along the north line of the county. The datum, low water in the river, is about 452 feet above tide. The flood plains on the west rise from 12 to 20 feet, a flood of 16 to 18 feet covering much the greater part with water. The second bottom rises about 30 feet above low water, and the bottoms of Brouillet's Creek are continuous with those of the river. The bluff on the west rises abruptly from Brouillet's Creek to an elevation of about 600 feet. On the east a rise of about 50 feet reaches the edge of a heavy gravel terrace, which rises gently toward the east, reaching an elevation of 520 feet at the foot of the island bluff one mile from the river. Thence across the island, whose higher points are about

600 feet above tide, to the terrace on the east at an elevation of 537 feet, about 85 feet above low water in the river. The next section, about three miles south, shows low bottoms on each side of the river, but no second bottoms. The big terrace near the river is perhaps a little higher than on the county line, but two broad valleys appear farther east which greatly reduce its volume. The third section, between three and four miles farther south, shows low bottoms, less than a mile wide, mainly east of the river. The terrace rises from the flood plain to an elevation of from 80 to 90 feet above low water, but soon descends to an elevation of only 45 to 50 feet above datum, in the valley of Otter Creek. Erosion by the creek may account for the great reduction in the volume of the terrace, as shown by this section. The section at Terre Haute, 3½ miles farther south, shows about one mile of low bottoms on the west, then a second bottom rising about 30 feet above low water, then low bottoms to the bluff. On the east a rise of 50 feet reaches the edge of the terrace, which rises gradually but irregularly to an elevation of about 70 feet at the bluff three miles from the river. Two low ridges and two shallow valleys occur on this section, but in general the surface of the terrace is more uniform than farther north. The next section, about four miles farther south, shows about one mile of flood plain on the west and a narrow terrace rising about 45 feet above low water in the river. On the east the terrace, nearly level, is about four miles wide, having an elevation of about 45 feet above low water. The ridges of the Terre Haute section show faintly, but the surface in general is uniform. The section three miles farther south, through the village of Prairieton, shows a little more than two miles of flood plain about equally divided by the river. The terrace about four miles wide has an average elevation of about 45 feet above low water. Honey Creek has cut a broad valley across the terrace, and a low ridge appears farther east. The next section, 3½ miles farther south, shows one mile of flood plain west of the river, and a narrow terrace. On the east the low bottoms are 3½ miles wide. A little island of gravel rising about 40 feet above low water, and a narrow sand ridge, are the sole representatives of the great terrace farther north. This section continued eastward shows that Johnson's Hill rises about 100 feet above low water in the river and that the valley of Prairie Creek, about one mile wide, has about the same elevation as the Prairieton terrace. It seems probable that Johnson's Hill was an island in the old river, and that the valley of Prairie Creek was the eastern channel of the ancient

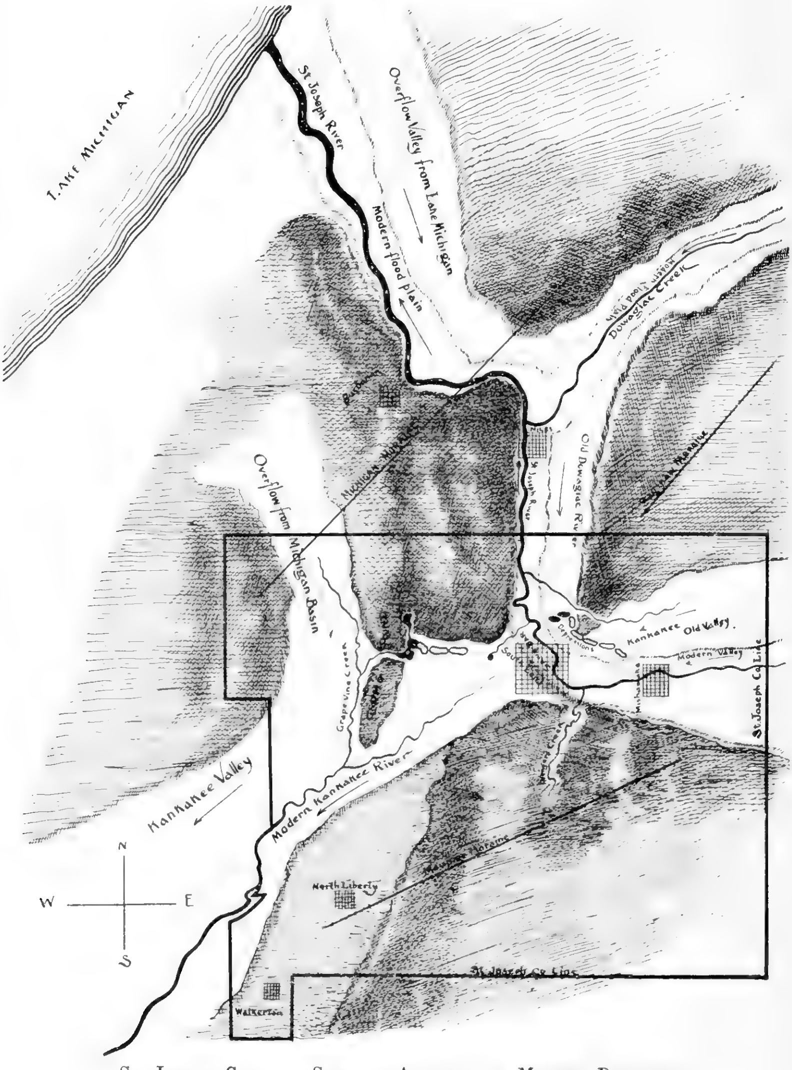
stream. The sand and gravel of Prairie Creek valley, probably representing the terrace, as shown in the Prairieton section. The section on the south county line shows three miles of flood plain east of the river. This plain is low along Prairie Creek and is crossed by a low, rocky ridge near the bluffs. West of the river the terrace is about two miles wide, with an average elevation of about 35 feet above low water in the river.



A low, broad ridge is shown upon the terrace, but in general its surface is quite uniform. This terrace descends gently toward the south so that at York, six miles south, it has an elevation of scant 30 feet above low water, while at Hutsonville, five miles below York, it has an elevation of only about 25 feet, just about on a level with the high floods, and only about 80 rods wide. Just north of Hutsonville there is a great hill of sand and gravel that rises about 45 feet above low water, but the greater part of the terrace is low. Thus the gravel terrace, so massive, so prominent a feature in Vigo County, almost disappears within 40 miles. It seems probable that the old valley was once filled with sand and gravel, at least to the elevation of the higher points of the present time. The present features of the valley are apparently due to extensive erosion. Meander lines run in 1816 show that the present river has not eroded its gravel banks to any appreciable extent during the past 80 years. The work of erosion signifies much stronger currents than prevail in the present river, even when in flood.

The Kankakee Valley. By H. T. Montgomery, M. D.

One of the great waterways during the ice period seems to have been entirely overlooked by our local and State geologists. I refer to the great Kankakee Valley, whose stream had its origin at the foot of the Saginaw glacier, and received tributary streams from the Maumee and Michigan glaciers, and became in time the outlet for the waters flowing south from Lake Huron through Saginaw Bay before they secured an outlet through the Niagara River. This great valley served as a waterway for the waters during the withdrawal of the first ice sheet, from the fact that its channel was silted up like all other great stream valleys during the Champlain epoch or age of depression, and was never re-excavated to any extent, and remains to-day a filled valley. It probably conveyed the waters during the advance of the last ice sheet, but soon after the sheet began to withdraw the waters found an outlet into Lake Michigan, leaving the Kankakee Valley at the point where South Bend now lies, through the bed of its largest tributary, which will be described later on. The Kankakee Valley extends from a point in Illinois where the present Kankakee River and the Desplaines unite, taking a northeasterly course through Illinois, Indiana and Michigan, to the watershed between the streams flowing into Saginaw Bay and the head-waters of the St. Joseph River, which flows southwest through the Kankakee channel to South Bend, where it abruptly turns north and reaches Lake Michigan at St. Joseph.



ST. JOSEPH COUNTY.—SHOWING ANCIENT AND MODERN DRAINAGE.

This valley was the great outlet to Lake Huron, as the Wabash Valley was the outlet to Lake Erie during glacial times. This great valley, with its flood plain, varies from three miles at its narrowest point, which is one mile below South Bend, to about twenty at its broadest part, which is between Porter and Lake on the north and Newton and Jasper counties on the south. The south bank of the valley from about six miles below South Bend to near its source is from fifty to one hundred feet high, while the north bank from South Bend to its source is generally low and shelving. From South Bend to the Illinois line, or from the point where the valley emerges from between the Maumee and Michigan moraines to its confluence with the Desplaines, the banks are low, generally not exceeding fifteen or twenty feet in height. On the south side of the old channel will be found quite an extensive sandy flood plain, extending from the border of the Maumee moraine southwestward, covering almost the entire surface of Starke County, the northern part of Pulaski, Jasper and Newton counties. On the north the main channel largely borders the Michigan moraine.

The great width of the stream from South Bend to the eastern part of Illinois was owing to three causes—first, the surface of the country through which this part of the stream flowed was destitute of rugged features, being a comparatively level, smooth surface; second, the stream crossed the arched condition of the bed rock which extends in a northwesterly course across Indiana into Illinois; this rocky ridge probably produced well-marked rapids, similar to those of the Ohio River near Louisville, and also had a marked tendency to dam the waters and cause them to overflow a wide territory above, giving to this region the general appearances of a great lake having occupied its territory; third, at South Bend, a tributary one-third its size was added to its volume; also the overflow from the Michigan basin through the Grapevine Valley.

The principal tributaries of the great Kankakee were the Elkhart and Yellow rivers, draining from the Maumee glacier, and probably the Tippecanoe River at a point where it enters the southeast corner of Starke County; this I have not carefully investigated, but which I think will probably be found to be a fact, also what I am pleased to call the great Dowagiac River, now represented by the Dowagiac Creek, which heads south of Kalamazoo, Mich., but the waters of whose ancient stream probably accumulated far north of that point, gathering all the glacial waters from the eastern slope of the eastern lateral moraine of the Michigan glacial lobe, forming a mighty glacial river, flowing south to a point three miles north of Niles, Mich., where it received a large tributary which had opened a way through the lateral Michigan moraine, and was discharging its waters from the Michigan basin, which had not yet found an opening to the south, between the Michigan ice lobe and its moraine. The Dowagiac River, after receiving the overflow waters from the Michigan basin, continued south and emptied its waters into the Kankakee at the present site of the city of South Bend.

The old channel where it emptied into the Kankakee is three miles wide, with well-defined banks rising from fifty to seventy-five feet above the bed of the valley, the valley having been cut to bed rock and silted up about 120 feet, leaving the above-mentioned banks yet remaining.

These great streams existed for long periods of time. The Kankakee and the Dowagiac conveying the glacial waters during the advance of the ice sheet, also during the period that it stood at its most advanced point, and during its withdrawal, until the Michigan ice lobe had sufficiently receded to allow the waters along its eastern border to escape through the Desplaines opening. This promoted a rapid lowering of the waters between the ice lobe and its terminal lateral moraine, and terminated the flow of waters from the Michigan basin into the Dowagiac River, leaving a broad water-worn plain leading from the Dowagiac River back northwestward to the Michigan basin.

Here commenced a system of river robbing. The Dowagiac River doubled upon itself at an angle of 45 degrees, followed the abandoned channel of its former tributary and discharged its waters into Lake Michigan, leaving in turn a well-worn channel from three to four miles wide and thirteen miles long, leading to the great Trunk Stream or Kankakee. The distance from the point where the Dowagiac emptied its waters into the Kankakee to St. Joseph, Mich., is thirty-eight miles, with a fall of 141 feet; from the same point to Momence, Ill., the distance is 92 miles. with a fall of 93 feet. It can be readily understood that, with the first annual flood, a part of the waters of the Kankakee would follow the abandoned Dowagiac channel, mingling with the Dowagiac, and onward into Lake Michigan at St. Joseph. The fall over the new route being three and a half times greater than that over the old route, the new channel rapidly cut through the old river deposit, finally claiming all of the waters of the once mighty Kankakee, leaving its valley from South Bend to the Desplaines a geological monument to tell of its eternal past.

The physical force which most likely turned the current of the Kankakee into the channel of the Dowagiac was an ice gorge, forming seven miles below South Bend, where a jutting point from the Michigan moraine extends out into the valley proper, two miles and a half, in an almost transverse direction, and known as Crum's Point. Just below this point we find an ancient flood plain two miles wide, which was supplied with overflow water from the Michigan basin, and which entirely subsided when the Michigan waters receded from the rim of its basin. This valley is drained by a small meandering stream, known as Grapevine Creek, the rudiment of a mighty glacial stream. Strong and well-pronounced evidences of an ice gorge or dam having formed at Crum's Point, and extending up the river to the mouth of the Dowagiac, are yet plainly visible, from the scouring, leveling and erosion of the morainic hills on the south, and a chain of lakes, and lake beds on the north, which are connected by a gorge through the point with the glacial stream mentioned above. And also at the head of the ice dam which passed well up above the mouth of the Dowagiac, where the waters pouring around it into the Dowagiac Valley excavated an interrupted channel, or chain of depression. These depressions are linear, extending from northwest to southeast, being from one-fourth to three-fourths of a mile long, twenty to forty feet deep, and from two hundred to six hundred yards wide, with sharp and well-defined banks. They all show evidences of having been filled with water for a long period of time. All have become dry except the lower two, which contain from twenty to thirty feet of water at present. This channel or chain of depressions extends from one mile north of South Bend southeasterly to within one mile of Mishawaka, a distance of four miles and a half, as shown on the accompanying diagram. When the ice dam gave way, the waters abandoned their circuitous routes and resumed their old channels, a part of them at this time taking the route down the Kankakee, and a part of them up the Dowagiac Valley, the fall the latter way being three and a half times greater than the former, a channel was soon eroded sufficiently to carry the entire volume of water. A bluff twelve to fourteen feet high, which commenced in the form of a sandbar, the sediment for which was supplied by what is known as Wenger's Creek, extending in a diagonal direction across the Kankakee bed, and parallel to the new current, until it reached the opposite bank, when the Kankakee Valley was sealed forever.

The Kankakee River, from its source to its mouth, took a southwesterly course. When the waters left the old channel they took an almost due northerly course, forming a great bend in the river, with its sharp convexity to the south, which gave our city its name—South Bend.

The two rivers since changing their course have eroded their valleys from fifty to seventy-five feet into the old river deposits, and have not yet attained their base level. The Kankakee Valley at South Bend, where it escapes from between the Maumee and the Michigan moraines, is narrowed down to three miles, with high rugged banks and no flood plain. Five miles east, and up the valley from South Bend, it attains a width of six miles, which width it holds with slight variation until it reaches the rim of the Saginaw basin. This end of the valley is thoroughly drained by the channel of the present St. Joseph River, which has eroded through the old river drift to the extent of from forty to fifty feet. There are a few peat bogs and marshes lying back from the river, where the valley is broad, and the modern channel well to one side. Otherwise the old valley above South Bend is one vast level sand plain. Below South Bend, where the old valley remains silted up, and there is no modern channel for drainage purposes, the spring waters escaping from beneath the Michigan moraine, and from the foot of the Maumee, also bubbling up from the bed of the old stream itself, as I am informed by Mr. William Whitten, in charge of rock excavations at Momence, has been productive of a vast growth of peat or muck over the entire valley proper, from South Bend to Momence. Beneath this peat bed, which ranges from six to ten feet in depth, is found fine sand and river gravel, as shown by excavations made in the construction of a large ditch made with the view of straightening the river. This ditch commences at South Bend, is twenty feet wide, ten feet deep, and twenty miles long, which gives us a comprehensive idea of the materials underlying the bog. If the stream had not changed its course at South Bend and continued down its original valley, eroding a channel or partially cleaning the old silted valley to a depth of from fifty to sixty feet, as the waters have done through their new course, rendering to the Kankakee Valley thereby proper drainage, there would never have been known a "Kankakee Marsh," but all that portion of Indiana would have been a vast sandy plain, covered with oak or barrens timber, and in general appearances the same as that part of the valley above South Bend.

Notes on the Eastern Escarpment of the Knobstone Formation in Indiana. By Lee F. Bennett.

One of the most noticeable topographical features of Indiana is the eastern escarpment of the Knobstone formation. It can easily be traced from New Albany in a north-northwesterly direction for more than one hundred miles.

The Knobstone formation comprises the lower strata of the Sub-carboniferous series in Indiana It is made up of clay shales, sandy shales and sandstones. The escarpment is due to a great thickness of the soft and easily eroded strata capped by more resisting strata of sandstone and overlying limestone. It generally faces east, and in the extreme southern part of the State it presents a bold precipitous face. Here the name "Knobs" is given to the range of hills formed by the escarpment; farther north this eastern portion of the formation is known as "the hills."

Beginning directly west of New Albany, in Section 3, township 3 south, range 6 east, the escarpment runs north ten miles. It varies from 190 feet to 385 feet above the country to the east which is low and flat and slopes gently towards the Ohio River. There are no foot-hills in this region, but in various places streams have cut through the escarpment forming narrow ravines with almost precipitous sides. With the exception of about two miles where limestone a few feet in thickness is found, sandstone is the capping stratum. In a typical section made six miles north of New Albany the sandstone was found to be 90 feet in thickness and the shale nearly 300 feet.

The drainage is toward the east into Silver Creek or southeast into the Ohio River. A few of the streams head two or three miles west of the escarpment and reach the level country through the narrow ravines before mentioned. The escarpment turns to the west in section 14, township 1 south and 6 east, Clark County, forming the southern boundary of the valley of Muddy Fork Creek as far as the town of Borden.

The knobs in this region vary from 150 to 250 feet in height and are capped by sandstone. Near Borden the knobs are for the most part made up of shales containing large quantities of iron nodules.

On the north side of the valley of Muddy Fork Creek the escarpment extends eastward to section 6, 1 south and 6 east, whence it runs in a north-northeasterly direction twelve miles to section 19, 2 north, 5 east, which is the most easterly extension of the Knobstone escarpment. Foothills are found in the northern part of township 1 north; they extend one mile to the east of the main escarpment, are low and for the most part uncultivated. The Sub-carboniferous limestone which overlies the Knobstone has receded many miles to the westward, thus leaving the sandstones and shales to make up the hills of this region. In section 24, 2 north and 8 east, on the line between Clark and Scott counties, probably the highest part of the escarpment is found; it is 400 feet above the general level of the country to the east. (The hills of section 24 and 25 are cut off from the main line by a gap cut by streams tributary to the Muscatatuck on the north and the Ohio on the south.)

The line of hills now turns westward, then northwestward twelve miles, passing into Washington County, and again turns west. In township 2 north, 6 east, there are several small valleys cut by streams tributary to the Muscatatuck. The foothills are long, extending two or three miles northeast parallel to the principal creek beds. In township 3 north, the overlying limestones extend to the eastern face of the Knob escarpment.

In section 30, township 4 north, 8 east, the hills turn to the west, running parallel to the Muscatatuck and White rivers. In places the hills "bluff up" against the river and in others the "bottom land" is a half mile or more in width. In the eastern part of township 4 north and 4 east, the line of hills makes a great bend towards the south; another deflection is made to the southeast in the middle of township 4 north and 3 east. In section 26, township 4 north and 2 east, in northwestern Washington County, limestone is found capping the escarpment 125 feet above the river bed and is found as the capping stratum for several miles farther down the river; the hills forming the border of the valley vary from 125 to 300 feet in height.

From Ft. Ritner, on the north side of White River, the hills extend northeast for six miles to near the town of Medora, then nearly north for ten miles to Freetown in the northwestern part of Jackson County. In the first seven miles of this portion there are no foothills, the White River bottoms extending to the face of the escarpment; farther north there are foothills and in many places there is a gradual rise from the eastern lowlands to the hills to the westward. In a few places only are the hills as high as they are to the south. One hill was measured which was 370 feet in height, but this was an exception. In the vicinity of Freetown, in township 6 north and 3 east, the highest hills along the eastern face are but little over 100 feet. They form the watershed for this section of the country.

East and south of Brownstown, in east-central Jackson County, are the "Brownstown Hills." They are outliers of the hills to the south and west. They are separated from the main line of hills to the south by the Muscatatuck River and two and one-half miles of bottom land; from those on the west, by the White River and four miles of bottom land. They are a very prominent feature in the topography of this region; their greatest extent is six miles from north to south and five miles from east to west. They are made up of muddy sandstones underlaid by clay shales and contain in many places considerable quantities of iron nodules. The hills in many places are nearly 400 feet above the valley; on the east the slope is rather abrupt, with few foothills, but on the west the slope is gradual to the White River bottoms. The hills are nearly cut through in three places by creeks tributary to the White River.

From Freetown the hills extend to the northeast six miles near the Bartholomew and Jackson county line, thence nearly north across the western part of Bartholomew County. Near the above-named county line one spur of the hills runs nearly east for three miles, then in a northerly direction, forming the foothills in Bartholomew County. The Knobstone escarpment is generally not well marked in this county. In a few places the slope is gradual; in other places the foothills are five or six miles wide and the escarpment is well marked. Without doubt two or three miles of these lower hills are partially formed of drift, as was shown by well sections obtained in this region; a few places along the west bank of Driftwood River there are bluffs 100 feet high.

The main escarpment varies from 100 to 275 feet above the immediate country to the east. The creek valleys in the lower hills are sometimes more than one-half mile in width. In the northern part of the county in township 10 north and 4 east, there is no distinct escarpment; the country gradually becomes more rolling from the east to the west and passes into the hills of northern Brown and southern Johnson counties.

Beginning with Johnson County the real eastern escarpment is covered with glacial material. In township 11 north and 5 east, extending to Sugar Creek west of Edinburg, the country is gently rolling with an occasional bluff on the west side of the creek; in township 11 north, 4 east, the hills are steeper and more numerous. In township 11 north 4 east, and 12 north 3 east, west and southwest of Franklin, the watershed between the east and west forks of White River is a ridge covered with a glacial material; it is almost level and from one to two miles in width.

The glacial covering can be easily traced along the southern part of this ridge. Here the wells are shallow and water is found in shale; farther north the water is found in gravel and sand, and in this region there is a number of large springs. Well sections also show the character of the original surface; of two wells within seventy-five yards of each other, one was 14 feet deep and the bottom was in blue shale; the other 41 feet deep and the bottom was in a "brush heap" (glacial debris).

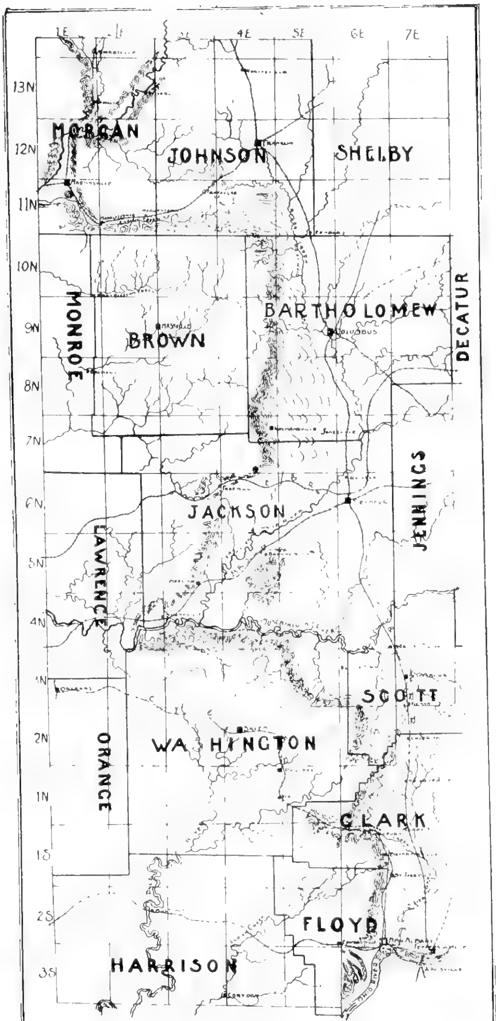
West of this ridge to White River, and especially along the creek beds, the country is very rough and shows the characteristic Knobstone topography. A continuation of the hills of northwest Bartholomew County are found in southern Johnson and Morgan counties; the hills are from 75 to 125 feet above the bed of Indian Creek which they follow to its mouth, three miles southwest of Martinsville.

On either side of White River north of Martinsville to near the Morgan and Johnson county lines, typical Knobstone bluffs are found. Directly west of Martinsville the bluff is 190 feet high. The bluffs on the west side follow close to the river for about five miles; they then turn to the north, forming the west side of the valley of White Lick Creek. They gradually become lower and can be traced two or three miles northwest of Mooresville, in township 14 north, 1 east, where they ceased to be noticeable. Between this spur and White River the country is gently rolling and covered to some depth with glacial material.

On the east side of the river most of the bottom land is found. It varies from a few hundred yards to three-quarters of a mile in width. The hills are not as high as on the west side and gradually become lower as they run northward. In section 2, township 13 north, 2 east, the last hill is found; at Waverly, two miles southeast, there is a sandstone quarry of typical "Knob" sandstone.

This northern portion is a good example of the gradual encroachment of drift material over the residual rock and soil.

In the accompanying map an attempt has been made to give a general idea of the location of the escarpment. The scale is too small to show only the larger valleys. The foothills are indicated by short contour lines some distance apart. No attempt has been made to show the height of the hills by a definite number of contours.



THE EASTERN ESCARPMENT OF THE KNOBSTONE FORMATION IN INDIANA

BY L. T. BENNETT OF THE INDIANA UNIVERSITY GEOLOGICAL SURVEY

An Old Shoreline. By D. W. Dennis.

The Elkhorn is a small tributary to the Whitewater River from the east, some four miles south of Richmond, Ind. There is in this stream a falls some twenty feet in height that has receded and left a gorge of about that depth for a distance of a half mile or more; this gorge is cut through strata of the same age as those through which the Niagara gorge passes. At the Elkhorn the surface rock is the Niagara limestone; it is massive and some twelve feet thick; it is underlaid by the uppermost layers of the Lower Silurian formation, consisting of alternating layers of thin flagstones and clay. This clay and fragile flags wear faster than the overlying massive rock, and so it shelves over; one can pass behind and around the falls just as he can parts of the Niagara Falls. The fossils in the Lower Silurian strata are the same one finds in the gorge at Richmond. In the uppermost stratum, however, they are beach-worn, ground in many instances to unrecognizable fragments; a half dozen species can, however, be made out—enough to settle the question of its age without dispute; it is Lower Silurian; it is an ancient coquina rock; it crops out for a distance of half a mile; tons of it can be examined; its story is as interesting as it is unmistakable; here was the beach of the Cincinnati Silurian Island; the wearing of the stones has not been in recent geological times, for they are restratified and are overlaid by the Niagara rock, which bears glacial striæ on its surface. After these rocks were beach-worn, the sea deepened, the shore line moved eastward and remained there long enough for the twelve feet of Niagara rock to form in a clear—clayless—sea.

Two Cases of Variation of Species with Horizon. By D. W. Dennis.

The east fork of the Whitewater River has worn a gorge in the upper strata of the Lower Silurian limestone, near Richmond, Ind. This gorge is about 75 feet deep, is terminated by a falls a half mile above the city, and for a distance of some two miles below the falls the river bluffs are generally precipitous. This Lower Silurian formation consists of flagstones four inches or less in thickness, alternating with clay strata of about the same thickness. The flags are made up chiefly of the shells of brachiopods, and these are in many places numerous in the accompanying clay strata; from these clay strata the shells weather out perfectly. This note concerns itself with two species of these brachiopods—Orthis biforata and Orthis occidentalis. The first of these has its hinge line sometimes greatly prolonged, as in Fig. (1). Every gradation in this respect is to be found as shown in Figs. (2), (3), (4) and (5). Specimens like Fig. (1) are to be found in the uppermost strata, and those with the hinge line less and less prolonged are found in lower and lower strata until finally in the lowest strata those without any prolongation—Fig. (5)—are to be found. The matter of interest is that the development of the hinge line went forward during the entire time of the formation of these rocks; its development is roughly in proportion to the altitude.

Forms like Figs. 4 and 5 continued to survive and are found at all horizons, but forms like Fig. 1 are not to be found at the lower horizons.

A similar change is to be noticed in Orthis occidentalis. Typical specimens of this species found at a low horizon have a channel along the middle line from the umbo to the anterior margin; see Fig. 6. But as one searches in higher and higher strata he finds the channel dying out and a ridge taking its place, until in the highest strata the typical species is displaced by its variety, Orthis sinuata, Fig. 7.

Notes on the Distribution of the Knobstone Group in Indiana.

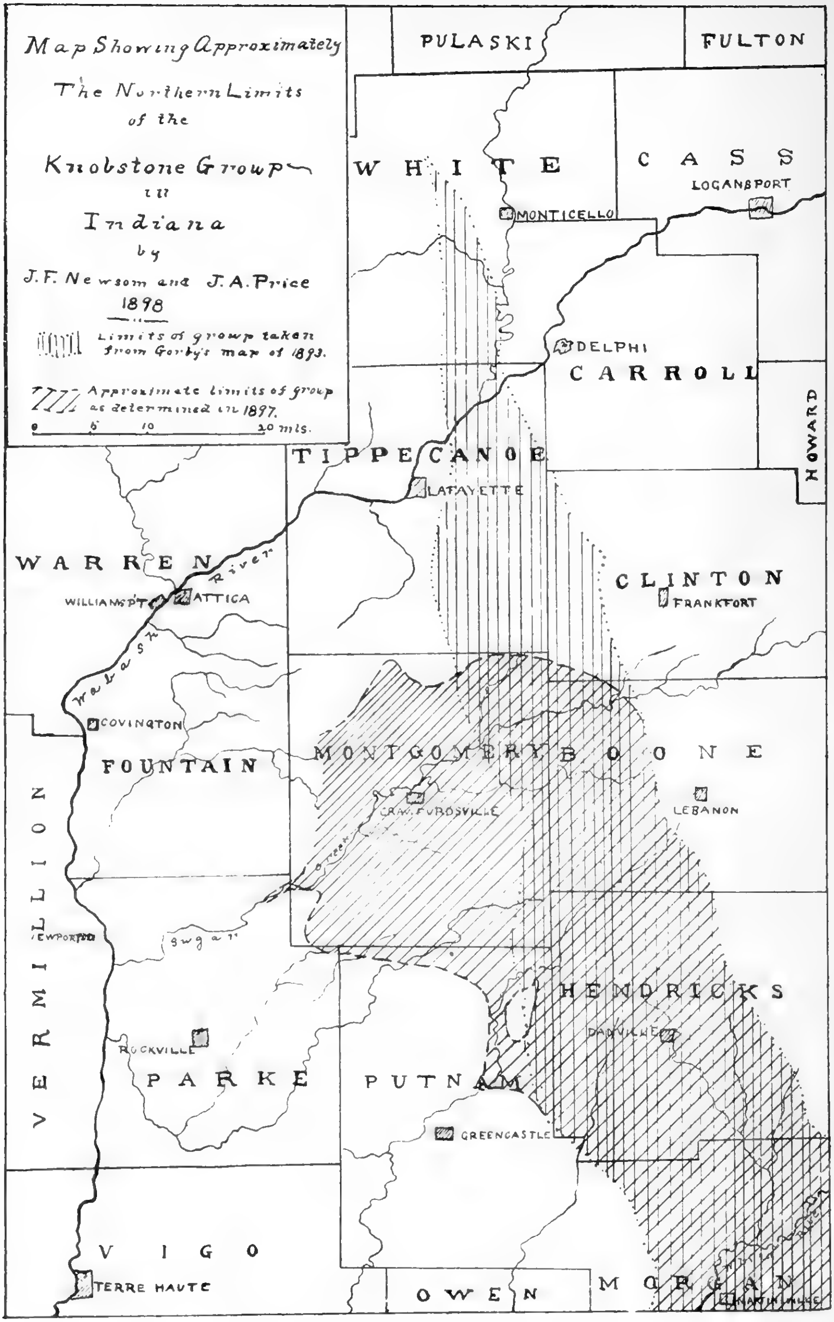
By J. F. Newsom and J. A. Price.

[Abstract.]

The series of shales and sandstones in Indiana known as the "Knobstone" has been grouped to itself principally because of its lithological characters. Because of its stratigraphical position with regard to the Lower Carboniferous limestones it has been regarded, in part at least, as the equivalent of the Kinderhook group of Illinois.

On Gorby's geological map of Indiana, of 1893, the Knobstone area is represented as extending as far northward as Honey Creek Township, in White County.

Field work done by the Indiana University Geological Survey in 1897 shows that the area underlain by the Knobstone does not extend so far north of Putnam County as has been hitherto suspected. It also seems



Map Showing Approximately
The Northern Limits
of the
Knobstone Group
in
Indiana
by
J. F. Newsom and J. A. Price
1898
Limits of group taken from Gorby's map of 1893.
Approximate limits of group as determined in 1897.
0 5 10 20 mls.
PULASKI
FULTON
WHITE
CASS
LOGANSPORT
MONTICELLO
DELPHI
CARROLL
HOWARD
TIPPECANOE
LAFAYETTE
WARREN
WILLIAMSP'T
ATTICA
Wabash River
CLINTON
FRANKFORT
COVINGTON
FOUNTAIN
MONTGOMERY
BOONE
CRAWFORDSVILLE
LEBANON
VERMILLION
NEWPORT
Sugar
HENDRICKS
DANVILLE
ROCKVILLE
PARKE
PUTNAM
GREENCASTLE
VIGO
TERRE HAUTE
OWEN
MORGAN
MARTINSVILLE

to show that the Crawfordsville crinoid beds, which have been regarded as belonging to the Keokuk, are the statigraphical equivalents of the Knobstone strata farther south.

The accompanying map shows the area covered by the Knobstone group, north of Morgan County, as that area is given on Gorby's geological map of 1893. It shows also (approximately) the area in and north of Putnam County as the field work of 1897 indicates it to be.

It will be noticed that (as worked out by the University Survey of 1897) no Knobstone is represented as occurring north of Montgomery County, while by far the larger part of that county is underlain by it.

Small isolated areas of the Knobstone may exist north of Montgomery County, but these will in all probability be found to be only outliers.

The limits of the area, as changed from Gorby's map of 1893, are only approximate. The whole region being covered over by glacial drift, except in the deepest creek valleys, makes it necessary to trace the contacts largely by well sections. It is consequently impossible to trace them more than approximately.

Some Indiana Mildews.* By M. A. Brannon.

Four years ago a paper on "Mildews of Indiana" was presented to you by Mr. J. N. Rose, of Wabash College. His was the first step toward determining the various species of Indiana mildews. The few species, and their hosts, named in this paper are the second attempt, I believe, in this State in the direction of determining these interesting parasites, which are everywhere abundant.

To Rose's list, containing the names of eleven species and twenty-nine hosts, are added several hosts for some of the species mentioned by him, also nine species and ten hosts not found in his list.

Bessey's "Erysiphe of the United States;" Cook's "Hand-Book of British Fungi;" Bull. of the Ill. State Laboratory of Nat. History, Vol. II., and Rose's "Mildews of Indiana" were the guides used in determining and describing the following species.

Sphærotheca Castagnei Lév.

*Paper read before the Indiana Academy of Science, 1889, and heretofore unpublished.

Found on leaves of Prænanthes altissima. Rose's additional notes to Cooke's description of this form do not state that some perithecia contain two asci. Such a case was observed in two or three perithecia of this species found on an Erigeron. In these unusual forms one ascus was much larger than its companion, but not as large as the ascus existing alone in a perithecium. A few of these unusual forms might lead to the questioning of what has, heretofore, been considered a strong generic difference between a Sphærotheca and an Erysiphe.

Podosphæra oxacantha DC. was found on cherry leaves. This species was named Podosphæra Kunzei by Dr. Bessey, but the reasons for changing to P. oxacantha are detailed in Bot. Gazette, Vol. XI, page 60, 1886.

Phylláctina suffulta Reb. (P. guttata Lév.).

Found sparingly on leaves of a Desmodium.

Uncinula flexuosa.

Occurred abundantly on leaves of the buckeye. This is a beautiful species and is characterized by wavy outlines of appendages at their extremities. It is amphigenous, appendages are hyaline, varying from thirty-six to fifty-six in number; asci, seven to twelve; spores, six to ten, and strongly pedicellate.

Uncinula Ampelopsidis Pk. was found in abundance on leaves of Ampelopsis quinquefolia. In the Trans. Albany Inst., Vol. VII, page 216, Peck includes U. Americana, U. spiralis and U. subfusca under the one name of Uncinula Ampelopsidis.

Uncinula adunca Lév.

Found very abundantly on willow leaves. It is amphigenous; has six to eight asci, and usually from four to six spores, rarely eight, in our species, though Bessey describes it with only four spores.

Uncinula circinnata C. and P.

On silver maple leaves.

Microsphæra Ravenelii B.

On leaves of honey locust. The repeated forking at the apices of the appendages makes the determination of this species very easy. It has from eight to sixteen appendages; asci, four to nine; spores, six to eight.

Microsphæra extensa C. and P.

Found on the upper surface of red oak leaves and on both sides of leaves from a young oak; the species was somewhat doubtful. Both specimens had very long appendages; from four to five asci; four to eight spores. A peculiarity was observed in the appendages of the perithecia borne on the leaves of the young oak. In many of the appendages were found swollen places resembling knee-like joints. These swellings were rather promiscuously arranged, having neither a definite location nor number on any appendage, which led to the opinion that the swellings were caused by some foreign growth. Closer observation revealed a mycelium running lengthwise the appendages and enlarging at the swollen places. This mycelium was observed, in one case, leaving the appendage and growing free from the host. Another view gave a mycelial thread of this same parasite, which, having twined itself about the apices of two appendages, was evidently drawing them together as if attempting to effect some way of reproducing itself, as is the custom of certain secondary parasites. This mycelium bore the same characteristic enlargements noted in the mycelium growing within the appendages. It acted and appeared, in many respects, like that parasite described and named Cincinobolus Cesatii by DeBary ("Die Pilze," p. 268), with this exception: He found this smaller parasite in the mycelium of mildews and not in the appendages of their perithecia. As it has been known to enter and develop its spores in the conidial chain, we may easily believe that it could make this further advance and take up its abode in the perithecia and their appendages. Granting that this secondary parasite may possibly be C. Cesatii, we have yet to dispose of the swellings borne on its mycelium. These swellings in no way resembled the reproductive organs of C. Cesatii figured and described by DeBary. They appear as internal growths of some other plant. It has been questioned whether these swellings may not be bacteroid forms existing on a secondary parasite of a primary parasite, thus giving the gradation of primary, secondary and tertiary parasitism. If so, it is desirable to allow the last two to remain in their epiparasitic habits and thus, as suggested by a German botanist (Thümen, "Pilze des Weinstocks," p. 178), they may exercise a restraining influence upon the first; and doubtless Cincinobolus does prevent the mildew from attaining its usual vigorous hold on the host plant. C. Cesatii has been found in the mycelium of some Erysiphe and Podosphæra species, but never, so far as could be learned, has it been found in an appendage nor in any part of a Microsphæra species, unless this be such a case.

Microsphæra densissima C. and P.

Very abundant on the oak leaf. This is a remarkably beautiful species growing its mycelium in orbicular and stellate patches, which enable one to recognize it at a glance.

Microsphæra diffusa C. and P.

On Desmodium leaves.

Erysiphe lamprocarpa (Wall.) Lév.

Found on many hosts, notably on Compositæ.

In addition to the host mentioned by Rose are added Aster cordifolius, Aster undulatus, Ambrosia trifida and Verbena stricta. In one instance a few asci were found containing three spores, which is contrary to what has formerly been regarded a strong specific character. This variableness of spores led to another classification of this species by Burrill and Earle (Bull. Ill. State Lab. Nat. History, Vol. II, p. 404).

Erysiphe Euphorbiæ Peck.

On Euphorbia corollata. The host bearing this species was in a withered and very sickly condition, whether from action of the mildew could not be affirmed.

Erysiphe communis (Wall.) Schl.

On Ranunculus recurvatus and an aster growing in the same place which had probably received the mildew from its neighbors. The appendages of the perithecium found on Ranunculus were fifteen to thirty-five in number and two to four times the diameter of the perithecia in length.

Erysiphe tortilis (Wall.) Lk.

On Clematis Virginiana. This species has been found on this host several times, but this specimen differed from all others described in apparently not affecting the host, which was in a vigorous condition, though the mildew was very abundant on its leaves.

Erysiphe horridula Lév.

On Verbena stricta and Eupatorium purpureum. It was difficult to decide whether this was E. horridula or E. lamprocarpa, as it closely resembles the latter, with the exception of having three to four spores in every ascus.

Recent research with improved instruments reveals many facts unknown to the early mycologists who made the first classification of mildews. Many of the characteristics forming generic and specific distinctions in their classification are found to be changeable and not always reliable, i. e., a Sphærotheca having two asci in a perithecium or an Erysiphe lamprocarpa having more than two spores in an ascus will not harmonize with a classification denying such variableness. Hence revisions are constantly being made, which have new characteristics as bases for new classifications, or extend the limits of these formerly too restricted species. But whatever advances may be made, the revisions must retain much of the old in the development of the new, for the first classification was correct in the main, and can be altered only in respect to details based on the more minute structure revealed by further investigation with greatly improved apparatus.

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Proceedings of the INDIANA ACADEMY OF SCIENCE

1899

PROCEEDINGS

OF THE

Indiana Academy of Science

1899.

EDITOR, - - GEO. W. BENTON.

ASSOCIATE EDITORS:

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THOMAS GRAY,
JOHN S. WRIGHT.

INDIANAPOLIS, IND.

1900.

INDIANAPOLIS:
WM. B BURFORD, PRINTER,
1900.

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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.]

Preamble.

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 body, 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,

Publication of the reports of the Indiana Academy of Science.

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.

Editing reports.

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 services, 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

Number of printed reports.

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. Proviso.

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 it 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 Indiana 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. Disposition of reports.

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. Emergency.

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

[Approved March 5, 1891.]

SECTION 1. *Be it enacted by the General Assembly of the State of Indiana*, That it shall be unlawful for any person to kill any wild bird other than a game bird, or purchase, offer for sale any such wild bird after it has been killed, or to destroy the nests or the eggs of any wild bird. Birds.

Sec. 2. For the purpose of this act the following shall be considered game birds; the Anatidæ, commonly called swans, geese, brant, and river and sea ducks; the Rallidæ, commonly known as rails, coots, mudhens, and gallinules; the Limicolæ, commonly known as shore birds, plovers, surf birds, snipe, woodcock and sandpipers, tattlers and curlews; the Gallinæ, commonly known as wild turkeys, grouse, prairie chickens, quail, and pheasants, all of which are not intended to be affected by this act.

Game birds.

Sec. 3. Any person violating the provisions of Section 1 of this act shall, upon conviction, be fined in a sum not less than ten nor more than fifty dollars, to which may be added imprisonment for not less than five days nor more than thirty days.

Penalty.

Sec. 4. Sections 1 and 2 of this act shall not apply to any person holding a permit giving the right to take birds or their nests and eggs for scientific purposes, as provided in Section 5 of this act.

Permits.

Sec. 5. Permits may be granted by the Executive Board of the Indiana Academy of Science 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 said Board written testimonials from two well-known scientific men certifying to the good character and fitness of said applicant to be entrusted with such privilege and pay to said Board one dollar to defray the necessary expenses attending the granting of such permit, and must file with said Board a properly executed bond in the sum of two hundred dollars, signed by at least two responsible citizens of the State as sureties. The bond shall be forfeited to the State and the permit become void upon proof that the holder of such permit has killed any bird or taken the nests or eggs of any bird for any other purpose than that named in this section and shall further be subject for each offense to the penalties provided in this act.

Permits to Science.

Bond.

Bond forfeited.

Sec. 6. The permits authorized by this act shall be in force for two years only from the date of their issue, and shall not be transferable.

Two years.

Sec. 7. The English or European House Sparrow (Passer domesticus), crows, hawks, and other birds of prey are not included among the birds protected by this act.

Birds of prey.

SEC. 8. All acts or parts of acts heretofore passed in conflict with the provisions of this act are hereby repealed. Acts repealed.

SEC. 9. An emergency is declared to exist for the immediate taking effect of this act, therefore the same shall be in force and effect from and after its passage. Emergency.

TAKING FISH FOR SCIENTIFIC PURPOSES.

Section 2, Chapter XXX, Acts of 1899, page 45, makes the following provision for the taking of fish for scientific purposes: "Provided, That in all cases of scientific observation he [the Commissioner of Fisheries and Game] shall require a permit from the Indiana Academy of Science."

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Geo. W. Benton, 525 N. Pennsylvania St., Indianapolis.

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1899-1900	D. W. Dennis	John S. Wright	E. A. Schultze	Geo. W. Benton	J. T. Scovell.

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 programmes 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 specially 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 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 evening 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.

R. J. Aley	*1898	Bloomington.
J. C. Arthur	1893	Lafayette.
P. S. Baker	1893	Greencastle.
George W. Benton	1896	Indianapolis.
A. J. Bigney	1897	Moore's Hill.
A. W. Bitting	1897	Lafayette.
Donaldson Bodine	1899	Crawfordsville.
W. S. Blatchley	1893	Indianapolis.
J. C. Branner	1893	Stanford University, Cal.
H. L. Bruner	1899	Irvington.
Wm. Lowe Bryan	1895	Bloomington.
Severance Burrage	1898	Lafayette.
A. W. Butler	1893	Indianapolis.
J. L. Campbell	1893	Crawfordsville.
John M. Coulter	1893	Chicago, Ill.
Stanley Coulter	1893	Lafayette.
Glenn Culbertson	1899	Hanover.
D. W. Dennis	1895	Richmond.
C. R. Dryer	1897	Terre Haute.
A. Wilmer Duff	1896	Lafayette.
C. H. Eigenmann	1893	Bloomington.
A. L. Foley	1897	Bloomington.
Katherine E. Golden	1895	Lafayette.
M. J. Golden	1899	Lafayette.
W. F. M. Goss	1893	Lafayette.
Thomas Gray	1893	Terre Haute.
A. S. Hathaway	1895	Terre Haute.
O. P. Hay	1893	Washington, D. C.
Robert Hessler	1899	Connersville.
H. A. Huston	1893	Lafayette.
J. P. D. John	1893	Greencastle.
D. S. Jordan	1893	Stanford University, Cal.
Arthur Kendrick	1898	Terre Haute.
Robert E Lyons	1896	Bloomington.
V. F. Marsters	1893	Bloomington.
C. L. Mees	1894	Terre Haute.
T. C. Mendenhall	1893	Worcester, Mass.
Joseph Moore	1896	Richmond.

*Date of election.

D. M. Mottier	*1893	Bloomington.
W. A. Noyes	1893	Terre Haute.
L. J. Rettger	1896	Terre Haute.
J. T. Scovell	1894	Terre Haute.
Alex. Smith	1893	Chicago, Ill.
W. E. Stone	1893	Lafayette.
Joseph Swain	1898	Bloomington.
M. B. Thomas	1893	Crawfordsville.
L. M. Underwood	1893	New York City.
C. A. Waldo	1893	Lafayette.
F. M. Webster	1894	Wooster, Ohio.
H. W. Wiley	1895	Washington, D. C.
John S. Wright	1894	Indianapolis.

NON-RESIDENT MEMBERS.

M. A. Brannon	Grand Forks, N. D.
D. H. Campbell	Stanford University, Cal.
B. W. Evermann	Washington, D. C.
Charles H. Gilbert	Stanford University, Cal.
C. W. Green	Stanford University, Cal.
C. W. Hargitt	Syracuse, N. Y.
Edward Hughes	Stockton, Cal.
O. P. Jenkins	Stanford University, Cal.
J. S. Kingsley	Tufts College, Mass.
D. T. MacDougal	Bronx Park, New York City.
Alfred Springer	Cincinnati, Ohio.
Robert B. Warder	Washington, D. C.
Ernest Walker	Clemson College, S. C.

ACTIVE MEMBERS.

G. A. Abbott	Duluth, Minn.
Frederick W. Andrews	Bloomington.
George H. Ashley	Indianapolis.
Edward Ayres	Lafayette.
Timothy H. Ball	Crown Point.
J. A. Bergström	Bloomington.
Edwin M. Blake	Lafayette.
Lee F. Bennett	Valparaiso.
M. C. Bradley	Bloomington.
Fred J. Breeze	Pittsburg.
Frank P. Bronson	Indianapolis.

*Date of election.

O. W. Brown ....Richmond.
A. Hugh Bryan ....Lafayette.
E. J. Chansler ....Bicknell.
Walter W. Chipman ....Warsaw.
George Clements ....Crawfordsville.
Charles Clickener ....Tangier.
Mel. T. Cook ....Greencastle.
U. O. Cox ....Mankato, Minn.
William Clifford Cox ....Columbus.
Albert B. Crowe ....Ft. Wayne.
M. E. Crowell ....Franklin.
Will Cumback ....Greensburg.
Edward Roscoe Cummings ....Bloomington.
Alida M. Cunningham ....Alexandria.
Martha Doan ....Westfield.
J. P. Dolan ....Syracuse.
Herman B. Dorner ....Lafayette.
Hans Duden ....Indianapolis.
Joseph Eastman ....Indianapolis.
E. G. Eberhardt ....Indianapolis.
M. N. Elrod ....Columbus.
F. L. Emory ....Morgantown, W. Va.
Percy Norton Evans ....Lafayette.
Samuel G. Evans ....Evansville.
J. E. Ewers ....
Carlton G. Ferris ....Big Rapids, Mich.
E. M. Fisher ....Urmeyville.
Austin Funk ....New Albany.
Robert G. Gillum ....Terre Haute.
Vernon Gould ....Rochester.
J. C. Gregg ....Brazil.
Alden H. Hadley ....Richmond.
U. S. Hanna ....Bloomington.
William M. Heiney ....Huntington.
Robert Hessler ....Connersville.
J. A. Hill ....
Frank C. Higgins ....Terre Haute.
Lucius M. Hubbard ....South Bend.
Alex. Johnson ....Ft. Wayne.
W. B. Johnson ....Franklin.
Ernest E. Jones ....Kokomo.
Chancey Juday ....Bloomington.
William J. Karslake ....Irvington.
D. S. Kelley ....Jeffersonville.
O. L. Kelso ....Terre Haute.

A. M. Kenyon .... Lafayette.
Ernest I. Kizer .... South Bend.
Charles T. Knipp .... Bloomington.
Thomas Large .... Urbana, Ill.
John Levering .... Lafayette.
V. H. Lockwood .... Indianapolis.
William A. Macbeth .... Terre Haute.
Robert Wesley McBride .... Indianapolis.
Rousseau McClellan .... Indianapolis.
G. W. Martin .... Nashville, Tenn.
Julius B. Meyer .... Lafayette.
O. M. Meyncke .... Brookville.
W. G. Middleton .... Richmond.
John A. Miller .... Bloomington.
W. J. Moenkhaus .... Huntingburg.
H. T. Montgomery .... South Bend.
J. P. Naylor .... Greencastle.
Charles E. Newlin .... Irvington.
John F. Newsom .... Stanford University, Cal.
E. W. Olive .... Indianapolis.
D. A. Owen .... Franklin.
Rollo J. Peirce .... Logansport.
W. H. Peirce .... Chicago, Ill.
Ralph B. Polk .... Greenwood.
James A. Price .... Ft. Wayne.
Frank A. Preston .... Indianapolis.
A. H. Purdue .... Fayetteville, Ark.
Ryland Ratliff .... Fairmount.
Claude Riddle .... Lafayette.
D. C. Ridgley .... Chicago, Ill.
Curtis A. Rinson .... Bloomington.
Giles E. Ripley .... Muncie.
George L. Roberts .... Greensburg.
D. A. Rothrock .... Bloomington.
John F. Schnaible .... Lafayette.
E. A. Schultze .... Ft. Wayne.
Howard Schurmann .... Indianapolis.
John W. Shepherd .... Terre Haute.
Claude Siebenthal .... Indianapolis.
J. R. Slonaker .... Bloomington.
Richard A. Smart .... Lafayette.
Lillian Snyder .... Lafayette.
William Stewart .... Lafayette.
J. M. Stoddard .... Crawfordsville.
Charles F. Stegmaier .... Greensburg.

Frank B. Taylor	Ft. Wayne.
S. N. Taylor	West Lafayette.
Erastus Test	Lafayette.
F. C. Test	Chicago, Ill.
J. F. Thompson	Richmond.
A. L. Treadwell	Oxford, Ohio.
Daniel J. Troyer	Goshen.
A. B. Ulrey	North Manchester.
E. Van Brumbaugh	Crawfordsville.
W. B. Van Gorder	Worthington.
Arthur C. Veatch	Rockport.
H. S. Voorhees	Brookville.
J. H. Voris	Huntington.
Fred C. Whitcomb	Delphi.
William M. Whitten	South Bend.
Guy Wilson	Greencastle.
Mae Woldt	Indianapolis
William Watson Woollen	Indianapolis.
A. J. Woolman	Duluth, Minn.
J. F. Woolsey	Indianapolis.
A. C. Yoder	Vincennes.
O. B. Zell	Clinton.

Fellows	52
Non-resident members	13
Active members	121
Total	186

LIST OF FOREIGN CORRESPONDENTS.

AFRICA.

Dr. J. Medley Wood, Natal Botanical Gardens, Berea Durban, South Africa.

South African Philosophical Society, Cape Town, South Africa.

ASIA.

China Branch Royal Asiatic Society, Shanghai, China.

Asiatic Society of Bengal, Calcutta, India.

Geological Survey of India, Calcutta, India.

Indian Museum of India, Calcutta, India.

India Survey Department of India, Calcutta, India.

Deutsche Gesellschaft für Natur- und Völkerkunde Ostasiens, Tokio, Japan.

Imperial University, Tokio, Japan.

Koninklijke Naturkundige Vereeniging in Nederlandsch-Indie, Batavia, Java.

Hon. D. D. Baldwin, Honolulu, Hawaiian Islands.

EUROPE.

V. R. Tschusizu Schmidhoffen, Villa Tannenhof, Halle in Salzburg, Austria.

Herman von Vilas, Innsbruck, Austria.

Ethnologische Mittheilungen aus Ungarn, Budapest, Austro-Hungary.

Mathematische und Naturwissenschaftliche Berichte aus Ungarn, Budapest, Austro-Hungary.

K. K. Geologische Reichsanstalt, Vienne (Wien), Austro-Hungary.

K. U. Naturwissenschaftliche Gesellschaft, Budapest, Austro-Hungary.

Naturwissenschaftlich-Medizinischer Verein in Innsbruck (Tyrol), Austro-Hungary.

Editors "Termeszetrajzi Fuzetk," Hungarian National Museum, Budapest, Austro-Hungary.

Dr. Eugen Dadai, Adj. am Nat. Mus., Budapest, Austro-Hungary.

Dr. Julius von Madarasz, Budapest, Austro-Hungary.

K. K. Naturhistorisches Hofmuseum, Vienna (Wien), Austro-Hungary.

Ornithological Society of Vienna (Wien), Austro-Hungary.

Zoologische-Bontanische Gesellschaft in Wien, Vienna, Austro-Hungary.

Dr. J. von Csato, Nagy Enyed, Austro-Hungary.

Malacological Society of Belgium, Brussels, Belgium.

Royal Academy of Science, Letters and Fine Arts, Brussels, Belgium.

Royal Linnean Society, Brussels, Belgium.

Societé Belge de Geologie, de Palaeontologié et Hydrologie, Brussels, Belgium.

Societé Royale de Botanique, Brussels, Belgium.

Societé Geologique de Belgique, Liège, Belgium.

Prof. Christian Frederick Lutken, Copenhagen, Denmark.

Bristol Naturalists' Society, Bristol, England.

Geological Society of London, London, England.

Dr. E. M. Holmes, British Pharm. Soc'y, Bloomsbury Sq., London, W. C., England.

Jenner Institute of Preventive Medicine, London, England.

Linnean Society of London, London, England.

Liverpool Geological Society, Liverpool, England.

Manchester Literary and Philosophical Society, Manchester, England.

"Nature," London, England.

Royal Botanical Society, London, England.
Royal Geological Society of Cornwall, Penzance, England.
Royal Microscopical Society, London, England.
Zoölogical Society, London, England.
Lieut.-Col. John Biddulph, 43 Charing Cross, London, England.
Dr. G. A. Boulenger, British Mus. (Nat. Hist.), London, England.
F. DuCane Godman, 10 Chandos St., Cavendish Sq., London, England.
Hon. E. L. Layard, Budleigh Salterton, Devonshire, England.
Mr. Osbert Salvin, Hawksford, Fernshurst, Haslemere, England.
Mr. Howard Saunders, 7 Radnor Place, Hyde Park, London W., England.
Phillip L. Sclater, 3 Hanover Sq., London W., England.
Dr. Richard Bowlder Sharpe, British Mus. (Nat His.), London, England.
Prof. Alfred Russell Wallace, Corfe View, Parkstone, Dorset, England.

Botanical Society of France, Paris, France.
Ministèrie de l'Agriculture, Paris, France.
Societé Entomologique de France, Paris, France.
L'Institut Grand Ducal de Luxembourg, Luxembourg, Lux., France.
Soc. de Horticulture et de Botan. de Marseille, Marseilles, France.
Societé Linneenne de Bordeaux, Bordeaux, France.
La Soc. Linneenne de Normandie, Caen, France.
Soc. des Naturelles, etc., Nantes, France.
Zoölogical Society of France, Paris, France.
Baron Louis d'Hamonville, Meurthe et Moselle, France.
Prof. Alphonse Milne-Edwards, Rue Cuvier, 57, Paris, France.
Pasteur Institute, Lille, France.

Botanischer Verein der Provinz Brandenburg, Berlin, Germany.
Deutsche Geologische Gesellschaft, Berlin, Germany.
Entomologischer Verein in Berlin, Berlin, Germany.
Journal für Ornithologie, Berlin, Germany.
Prof. Dr. Jean Cabanis, Alte Jacob Strasse, 103 A., Berlin, Germany.
Augsburger Naturhistorischer Verein, Augsburg, Germany.
Count Hans von Berlspsen, Münden, Germany.
Braunschweiger Verein für Naturwissenschaft, Braunschweig, Germany.

Bremer Naturwissenschaftlicher Verein, Bremen, Germany.

Kaiserliche Leopoldische-Carolinische Deutsche Akademie der Naturforscher, Halle, Saxony, Germany.

Königlich-Sächsische Gesellschaft der Wissenschaften, Mathematisch-Physische Classe, Leipzig, Saxony, Germany.

Naturhistorische Gesellschaft zu Hannover, Hanover, Prussia, Germany.

Naturwissenschaftlicher Verein in Hamburg, Hamburg, Germany.

Verein für Erdkunde, Leipzig, Germany.

Verein für Naturkunde, Wiesbaden, Prussia.

Belfast Natural History and Philosophical Society, Belfast, Ireland.

Royal Dublin Society, Dublin.

Societa Entomologica Italiana, Florence, Italy.

Prof. H. H. Giglioli, Museum Vertebrate Zoölogy, Florence, Italy.

Dr. Alberto Perngia, Museo Civico di Storia Naturale, Genoa, Italy.

Societa Italiana de Scienze Naturali, Milan, Italy.

Societa Africana d' Italia, Naples, Italy.

Dell 'Academia Pontifico de Nuovi Lincei, Rome, Italy.

Minister of Agriculture, Industry and Commerce, Rome, Italy.

Rassegna della Scienze Geologiche in Italia, Rome, Italy.

R. Comitato Geologico d' Italia, Rome, Italy.

Prof. Count. Tomasso Salvadori, Zoölog. Museum, Turin, Italy.

Royal Norwegian Society of Sciences, Throndhjem, Norway.

Dr. Robert Collett, Kongl. Frederiks Univ., Christiana, Norway.

Academia Real des Sciencias de Lisboa (Lisbon), Portugal.

Comité Geologique de Russie, St. Petersburg, Russia.

Imperial Academy of Sciences, St. Petersburg, Russia.

Imperial Society of Naturalists, Moscow, Russia.

The Botanical Society of Edinburgh, Edinburgh, Scotland.
John J. Dalgleish, Brankston Grange, Bogside Sta., Sterling, Scotland.
Edinburgh Geological Society, Edinburgh, Scotland.
Geological Society of Glasgow, Scotland.
John A. Harvie-Brown, Duniplace House, Larbert, Stirlingshire, Scotland.
Natural History Society, Glasgow, Scotland.
Philosophical Society of Glasgow, Glasgow, Scotland.
Royal Society of Edinburgh, Edinburgh, Scotland.
Royal Physical Society, Edinburgh, Scotland.

Barcelona Academia de Ciencias y Artes, Barcelona, Spain.
Royal Academy of Sciences, Madrid, Spain.
Institut Royal Geologique de Suède, Stockholm, Sweden.
Societé Entomologique à Stockholm, Stockholm, Sweden.
Royal Swedish Academy of Science, Stockholm, Sweden.
Naturforschende Gesellschaft, Basel, Switzerland.
Naturforschende Gesellschaft in Berne, Berne, Switzerland.
La Societé Botanique Suisse, Geneva, Switzerland.
Societé Helvetique de Sciences Naturelles, Geneva, Switzerland.
Societé de Physique et d' Historie Naturelle de Geneva, Geneva, Switzerland.
Concilium Bibliographicum, Zürich-Oberstrasse, Switzerland.
Naturforschende Gesellschaft, Zürich, Switzerland.
Schweizerische Botanische Gesellschaft, Zürich, Switzerland.
Prof. Herbert H. Field, Zürich, Switzerland.

AUSTRALIA.

Linnean Society of New South Wales, Sidney, New South Wales.
Royal Society of New South Wales, Sidney, New South Wales.
Prof. Liveridge, F. R. S., Sidney, New South Wales.
Hon. Minister of Mines, Sidney, New South Wales.
Mr. E. P. Ramsey, Sidney, New South Wales.
Royal Society of Queensland, Brisbane, Queensland.
Royal Society of South Australia, Adelaide, South Australia.
Victoria Pub. Library, Museum and Nat. Gallery, Melbourne, Victoria.
Prof. W. L. Buller, Wellington, New Zealand.

NORTH AMERICA.

Natural Hist. Society of British Columbia, Victoria, British Columbia.

Canadian Record of Science, Montreal, Canada.

McGill University, Montreal, Canada.

Natural Society, Montreal, Canada.

Natural History Society, St. Johns, New Brunswick.

Nova Scotia Institute of Science, Halifax, N. S.

Manitoba Historical and Scientific Society, Winnepeg, Manitoba.

Dr. T. McIlwraith, Cairnbrae, Hamilton, Ontario.

The Royal Society of Canada, Ottawa, Ontario.

Natural History Society, Toronto, Ontario.

Hamilton Association Library, Hamilton, Ontario.

Canadian Entomologist, Ottawa, Ontario.

Department of Marine and Fisheries, Ottawa, Ontario.

Ontario Agricultural College, Guelph, Ontario.

Canadian Institute, Toronto.

Ottawa Field Naturalists' Club, Ottawa, Ontario.

University of Toronto, Toronto.

Geological Survey of Canada, Ottawa, Ontario.

La Naturaliste Canadian, Chicontini, Quebec.

La Naturale Za, City of Mexico.

Mexican Society of Natural History, City of Mexico.

Museo Nacional, City of Mexico.

Sociedad Cientifica Antonio Alzate, City of Mexico.

Sociedad Mexicana de Geographia y Estadistica de la Republica Mexicana, City of Mexico.

WEST INDIES.

Victoria Institute, Trinidad, British West Indies.

Museo Nacional, San Jose, Costa Rica, Central America.

Dr. Anastasia Alfaro, Secy. National Museum, San Jose, Costa Rica.

Rafael Arango, Havana, Cuba.

Jamaica Institute, Kingston, Jamaica, West Indies.

SOUTH AMERICA.

Argentina Historia Natural Florentine Amegline, Buenos Ayres, Argentine Republic.

Musée de la Plata, Argentine Republic.

Nacional Academia des Ciencias, Cordoba, Argentine Republic.

Sociedad Cientifica Argentina, Buenos Ayres.

Museo Nacional, Rio de Janeiro, Brazil.

Sociedad de Geographia, Rio de Janeiro, Brazil.

Dr. Herman von Jhering, Dir. Zoöl. Sec. Con. Geog. e Geol. de Sao Paulo, Rio Grande do Sul, Brazil.

Deutscher Wissenschaftlicher Verein in Santiago, Santiago, Chili.

Societé Scientifique du Chili, Santiago, Chili.

Sociedad Guatemalteca de Ciencias, Guatemala, Guatemala.

. . . PROGRAM . . .

OF THE

FIFTEENTH ANNUAL MEETING

OF THE

Indiana Academy of Science,

STATE HOUSE, INDIANAPOLIS,

December 27 and 28, 1899.

OFFICERS AND EX-OFFICIO EXECUTIVE COMMITTEE.

C. H. EIGENMANN, President, D. W. DENNIS, Vice-President, JOHN S. WRIGHT, Secretary.
E. A. SCHULTZE, Asst. Secretary. GEO. W. BENTON, Press Secretary.
J. T. SCOVELL, Treasurer.

C. A. WALDO,	W. A. NOYES,	O. P. HAY,	J. P. D. JOHN,
THOMAS GRAY,	J. C. ARTHUR,	T. C. MENDENHALL,	JOHN M. COULTER,
STANLEY COULTER,	J. L. CAMPBELL,	JOHN C. BRANNER,	DAVID S. JORDAN.
AMOS W. BUTLER,			

The sessions of the Academy will be held in the State House, in the rooms of the State Board of Agriculture.

Headquarters will be at the Bates House. A rate of $2.00 and up per day will be made to all persons who make it known at the time of registering that they are members of the Academy.

Reduced railroad rates for the members can not be obtained under the present ruling of the Traffic Association. Many of the colleges can secure special rates on the various roads. Those who can not do this, could join the State Teachers' Association and thus secure a one and one-third round trip fare.

M. B. THOMAS,
C. R. DRYER,
Committee.

GENERAL PROGRAM.

WEDNESDAY, DECEMBER 27.

Meeting of Executive Committee at the Hotel Headquarters .... 8 P. M.

THURSDAY, DECEMBER 28.

General Session .... 9 a. m. to 12 m.
Sectional Meetings .... 2 p. m. to 5 p. m.

LIST OF PAPERS TO BE READ.

ADDRESS BY THE RETIRING PRESIDENT,

PROFESSOR C. H. EIGENMANN,

At 10 o'clock Thursday morning.

Subject: "Degeneration Illustrated by the Eyes of the Cave Fishes."

The following papers will be read in the order in which they appear on the program, except that certain papers will be presented *"pari passu"* in sectional meetings. When a paper is called and the reader is not present, it will be dropped to the end of the list, unless by mutual agreement an exchange can be made with another whose time is approximately the same. Where no time was sent with the papers, they have been uniformly assigned ten minutes. Opportunity will be given after the reading of each paper for a brief discussion.

N. B.—By the order of the Academy, no paper can be read until an abstract of its contents or the written paper has been placed in the hands of the Secretary.

GENERAL.

1. The Florida Gopher, 30 m. .... W. B. Fletcher
2. Libraries of Microscopical Slides, 5 m. .... A. J. Bigney
3. A Method of Registration for Anthropological Purposes, 10 m., ... A. W. Butler

*4. A Vacation Trip to the San Marcos, Texas, Caves and Springs, 15 m. .... C. H. Eigenmann

*5. A New Pathogenic Yeast, 12 m. .... R. Lyons and L. Rettger

6. Aids in Teaching Physical Geography, 10 m. .... V. F. Marsters
7. Some Preliminary Notes on the Hygienic Value of Various Street Pavements as Determined by Bacteriological Analyses, 10 m. .... Severance Burrage and D. B. Luten
8. Insects as Factors in the Spread of Bacterial Diseases, 20 m., ... Severance Burrage
9. House Boats for Biological Work, 10 m. .... U. O. Cox

MATHEMATICS AND PHYSICS.

10. Tests on Some Ball and Roller Bearings, 12 m. .... M. J. Golden
11. Bearing-Testing Dynamometer, 10 m. .... M. J. Golden
12. The Toepler-Holtz Machine for Roentgen Rays, 5 m. ... J. L. Campbell

* Author absent, paper not presented.

13. A Proposed Notation for the Geometry of the Triangle, 5 m., ...R. J. Aley
14. Some Circles Connected with the Triangle, 8 m...........R. J. Aley
15. The Point P and Some of its Properties, 8 m..............R. J. Aley
*16. Applications of Group Theory, 5 m..................D. A. Rothrock
*17. Singularities of Certain Continuous Groups, 5 m......E. W. Rettger
*18. On a Family of Warped Surfaces Connected by a Simple Functional Relation, 20 m...C. A. Waldo and B. C. Waldenmaier
19. Diamond Fluorescence, 10 m..........................A. L. Foley
20. Some Experiments on Locomotive Combustion, 10 m..J. W. Shepherd

CHEMISTRY.

21. Some Ionization Experiments, 10 m....................P. N. Evans
22. Synthesis of the 2-3, 3-Trimethyl cyclopentanone, a cyclic derivative of Camphor, 10 m.....................W. A. Noyes

BOTANY.

23. Contributions to the Flora of Indiana, VI, 10 m......Stanley Coulter
24. Some Unrecognized Forms of Native Trees, 10 m....Stanley Coulter
25. Seedlings of Certain Native Herbaceous Plants, 10 m........ ....Stanley Coulter and Herman Dorner
26. The Resin Ducts and Strengthening Cells of Abies and Picea, 10 m ....Herman Dorner
*27. Karyokinesis in Magnolia with Special Reference to the Behavior of the Chromosomes, 10 m................F. M. Andrews
28. A Proteolytic Enzyme of Yeast, 15 m..........Katherine E. Golden
29. Saccharomyces anomalus Hausen (?), 10 m.....Katherine E. Golden
30. Some Problems in Corallorhiza, 8 m.................M. B. Thomas
31. Disappearance of Sedum ternatum, 5 m..............M. B. Thomas

ZOOLOGY.

*32. The Kankakee Salamander, 5 m.........................T. H. Ball
33. The Eye of the Mole, 5 m............................J. R. Slonaker
34. Notes on Indiana Birds, 10 m........................A. W. Butler
35. Biological Conditions of Round and Shriner Lakes, Whitley County, Indiana, 10 m........................E. B. Williamson

* Author absent, paper not presented.

*36. The Arthropods of the San Marcos Caves and Springs, 10 m., ...Carl Ulrich

*37. The Retinal Pattern of Single and Double Cones in the Eyes of Fishes, 10 m..................C. H. Eigenmann and G. Shafer

*38. Some Notes on the Blind Fish Caves at Mitchell, Indiana, 5 m ....C. H. Eigenmann

39. The Eyes of Cambrus pellucidus from Mammoth Cave, 10 m ....F. M. Price

*40. The Optic Lobes of the Blind Fish, Amblyopsis, 10 m..E. E. Ramsey

*41. The Cold-Blooded Vertebrates of Winona Lake and its Vicinity, 5 m...E. E. Ramsey

42. Cortex Cells of the Mouse's Brain, 10 m...............D. W. Dennis

*43. Cocoon Spinning in Lycosa, 5 m..................W. J. Moenkhaus

*44. Some Hybrid Fishes, 10 m........................W. J. Moenkhaus

GEOLOGY.

45. The Physical Geography of the Region of the Great Bend of the Wabash, 10 m.............................W. A. McBeth

46. An Interesting Bowlder, 5 m........................W. A. McBeth

47. The Headwaters of Salt Creek in Porter County, Indiana, 10 m ....L. F. Bennett

48. Weathering and Erosion of North and of South Slopes, 8 m., ...G. Culbertson

49. A Cranium of Castoroides found at Greenfield, Indiana, 5 m., ...Joseph Moore

50. On the Waldron Fauna at Tarr Hole, Indiana, 10 m..E. R. Cumings

51. The Stream Gradients of the Lower Mohawk Valley, 10 m., ...E. R. Cumings

52. Skull of Fossil Bison, 10 m......W. G. Middleton and Joseph Moore

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*Author absent, paper not presented.

THE FIFTEENTH ANNUAL MEETING OF THE INDIANA ACADEMY OF SCIENCE.

The fifteenth annual meeting of the Indiana Academy of Science was held in Indianapolis, Thursday, December 28, 1899, preceded by a session of the Executive Committee of the Academy, 9 p. m., Wednesday, December 27.

At 9 a. m., December 28, in the absence of the President, C. H. Eigenmann, Vice President D. W. Dennis called the Academy to order in general session, at which committees were appointed and other routine and miscellaneous business transacted. After the disposition of these affairs, the address of the retiring President, Dr. C. H. Eigenmann, was read by the Vice President, Dr. D. W. Dennis; subject, "Degeneration Illustrated by the Eyes of Cave Fishes." Following this address, until adjournment at 12 m., the Academy was engaged with the papers of the printed program under the title, "General Subjects."

At 2 p. m. the Academy met in two sections—biological and physico-chemical—for the reading and discussion of papers. Vice President Dennis presided over the biological section, while G. W. Benton acted as chairman of the physico-chemical section. At 5 p. m. the section meetings adjourned and the Academy was assembled in general session for the transaction of business.

Adjournment, 5:30 p. m.

THE FIELD MEETING OF 1899.

The Field Meeting of 1899 was held at Crawfordsville, Thursday, Friday and Saturday, May 25, 26 and 27.

At 8:30 p. m. Thursday, the Executive Committee met for the transaction of business.

Friday the 26th was spent in the field. Leaving Crawfordsville early in the morning, the party traveled by carriages to Pine Hills, a district which afforded excellent field opportunities to the botanists, zoologists and geologists. The return to Crawfordsville was made by way of Alamo and Yountsville. In the evening the Academy was given a reception at the residence of President Burroughs, of Wabash College.

On Saturday the members made field excursions to the north of Crawfordsville, visiting the well-known crinoid beds along Sugar Creek.

The Academy is greatly indebted to the local members for their generous and thoughtful hospitality, which was a prominent feature of the meeting.

PRESIDENT'S ADDRESS.

DEGENERATION IN THE EYES OF THE COLD-BLOODED VERTEBRATES OF THE NORTH AMERICAN CAVES.

By C. H. Eigenmann.

"Degeneration," says Lankester, "may be defined as the gradual change of the structure in which the organism becomes adapted to less varied and less complex conditions of life; whilst elaboration is a gradual change of structure in which the organism becomes adapted to more and more varied and complex conditions of existence."

Degeneration may affect the organism as a whole or some one part. I propose to speak not on degeneration in general but to give a concrete example of the degeneration of the parts of one organ.

The eyes of the blind vertebrates of North America lend themselves to this study admirably, because different ones have reached different stages in the process, so by studying them all we get a series of steps through which the most degenerate has passed, and are enabled to reach conclusions that the study of an extreme case of degeneration would not give us.

I shall confine myself to the cave salamanders and the blind fishes (Amblyopsidae) nearly all of which I have visited in their native haunts. The salamanders are introduced to illuminate some dark points in the degeneration of the eyes of the fishes and to emphasize a fact that is forcing itself forward with increasing vehemence; i. e., that cross-country conclusions are not warrantable; that the blind fishes form one group and the salamanders other groups, and that however much one may help us to understand the other, we must not expect too close an agreement in the steps of their degeneration under similar conditions.

There are three cave salamanders in North America.

1. Spelerpes maculicauda is found generally distributed in the caves of the Mississippi Valley. It so closely resembles Spelerpes longicauda that it has not, until more recent years, been distinguished from the latter, which has an even wider epigæan distribution. There is nothing about the structure of the salamander that marks it as a cave species, but its habits are conclusive.

2. Typhlotriton is much more restricted in its distribution, being confined to a few caves in southwestern Missouri. I have taken its larvae at the mouth of Rock House Cave in abundance. In the deeper recesses of Marble Cave I secured both young and adult. This is a cave species of a more pronounced type. The very habit that accounts for the presence of salamanders in caves has been retained by this one. I found some individuals hiding (?) under rocks, and in the aquarium their stereotropic nature manifests itself by the fact that they crawl into glass tubing, rubber tubing or under wire screening. In the eye of this species we have some of the early steps in the process of degeneration.

3. Typhlomolge has been taken from a surface well near San Marcos, Texas, and from the artesian well of the U. S. Fish Commission at the same place. The artesian well taps a cave stream about 190 feet from the surface. It has also been seen in the underground stream of Ezel's Cave near San Marcos. It was also reported to me from South of San Antonio, Texas. This is distinctly and exclusively a cave species, and its eyes are more degenerate than those of any other salamander, including the European Proteus.*

The Amblyopsidae are a small family of fresh-water fishes and offer exceptional facilities for the study of the steps in the degeneration of eyes. There are at least six species and we have gradations in habits from permanent epigæan species to species that have for ages been established in caves.

The species of Chologaster possess well developed eyes. One of them, C. cornutus, is found in the coast streams of the southeastern States; another, C. papilliferus, is found in some springs in southwestern Illinois, while the third, C. agassizii, lives in the cave streams of Kentucky and Tennessee.

The other members of the family are cave species with very degenerate eyes. They represent three genera which are descended from three epigæan species. Amblyopsis, the giant of the race, which reaches 135

* It may be noticed that the eyes of the western Typhlotriton are more degenerate than those of the cave Spelerpes of wider distribution. Further the eyes of the Texas Typhlomolge are more degenerate than those of the Missouri Typhlotriton. Similarly the Missouri blind fish Troglichthys has eyes in a much more advanced state of degeneration than the Ohio valley blind fishes. It is possible that the explanation is to be found in the length of time the caves in these regions have been habitable. During the glacial epoch the caves of the Ohio valley were near the northern limit of vegetation. The Missouri caves, if affected at all by glaciation, must have become habitable before those of the Ohio valley, while those of Texas were probably not affected at all.

mm. in length, is found in the caves of the Ohio Valley. Typhlichthys is also found in the Ohio valley but chiefly south of the Ohio River. But a single specimen has been found north of the Ohio, and this specimen represents a distinct species. Troglichthys, which is found in the caves of Missouri, has been in caves longer than its relatives, if the degree of the degeneration of its eyes is a criterion.

Before dealing with the degeneration of the eye a few words are in order on the normal structure of the organ under consideration.

In the normally developed eye we may distinguish a variety of parts with different functions. These are:

A. Organs for protection like the lid and orbits.

B. Organs for moving the eye to enable it to receive direct rays of light. In the cold-blooded vertebrates these consist of four rectus muscles and two oblique.

C. Organs to support the active structures, the fibrous or cartilaginous sclera.

D. The eye proper, consisting of:

1. Parts for transmitting and focusing light; the cornea, lens and vitreous body.

2. Parts for receiving light and transforming it to be transmitted to the brain; the retina.

3. A part for transmitting the converted impression to the brain; the optic nerve.

Some of these, as the muscles, retina and optic nerve, are active, while others, the dioptric, protective and supporting organs, are passive.

A. In the Amblyopsidae the skin passes directly over the eye without forming a free orbital rim or lid. The skin over the eye in Chologaster is much thinner than elsewhere and free from pigment. In the other genera of the family the eye has been withdrawn from the surface. In these it lies deep beneath the skin, and the latter, where it passes over the eye, has assumed the structure normal to it in other parts of the head.

In the salamanders we have a perfect gradation in the matter of the eye lids. In Spelerpes a free orbital rim is present in every respect like that found in epigæan salamanders. In Typhlotriton the lids are closing over the eye. The slit between the upper and the lower lid is much shorter than usual, and the upper lid overlaps the lower. The conjunctiva is still normal. The eye of this species is midway between the normal salamander eye and that of Typhlomolge in which a slight thinning of the skin is all there is to indicate its former modification over the eye.

B. The muscles to change the direction of the eye ball show complete gradations from perfect development to total disappearance. In the species of Chologaster all the muscles are normally developed. In Amblyopsis the muscles are unequally developed, but one or more are always present and can be traced from their origin to the eye. In Troglichthys the distal halves of the muscles, the parts nearest the eye, have been replaced by connective tissue fibers; i. e., a tendon has replaced part of the muscle. Here we have a step in advance in the degeneration found in Amblyopsis and no instance was noticed where all the muscles of any eye were even developed in the degree described. In Typhlichthys the muscles have all disappeared.

In Typhlomolge the muscles have disappeared; in the other salamanders they are present.

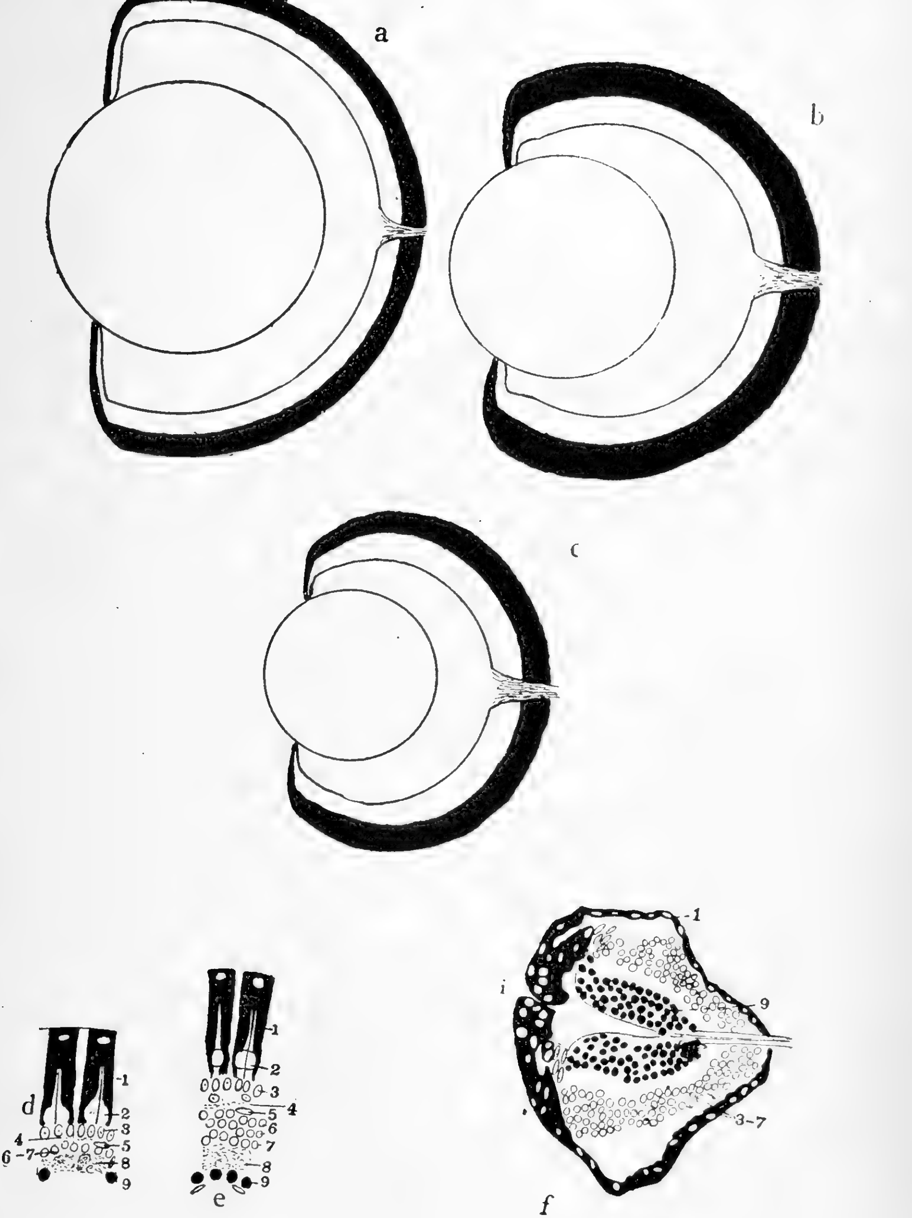
C. The sclera is indifferently developed in Chologaster and there is but little modification in the species with more degenerate eyes, except that in Amblyopsis and Troglichthys where cartilaginous bands were evidently present in the epigæan ancestors these bands have persisted in a remarkable degree, being much too large for the minute eye with which they are connected. In Troglichthys they form a hood over the front of the eye and various projections and angles in their endeavor to accommodate themselves to the small structure which they cover.

This is in striking contrast to the condition in Typhlotriton where but a single slight nodule of cartilage remains. Even this is frequently absent in the adult, while in the larvae of the same species a cartilaginous band extends almost around the equator of the eye. The different effect of degeneration in the Amblyopsidae and the salamander could not be more forcibly illustrated than by the scleral cartilages. The presence of a cartilagenous band in the young is, possibly, a larval character, and its absence in the adult has, in that case, no bearing on phylogenetic degeneration.

D. The eye as a whole and its different parts may now be considered.

1. The dioptric apparatus.

The steps in the degeneration of the eye in general are indicated in the accompanying figures.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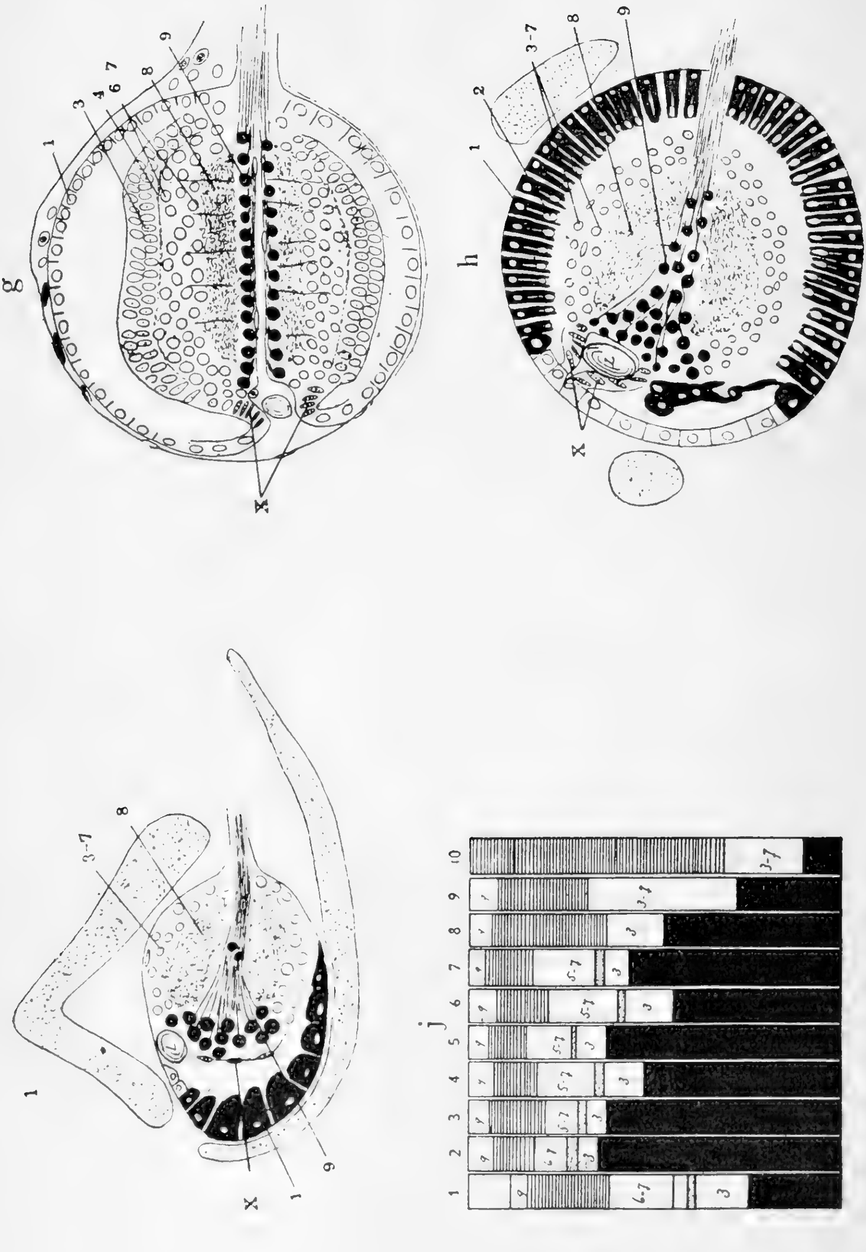
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EXPLANATION OF FIGURES.

A.—I. Diagrams of the eyes of all the species of the Amblyopsidae and of Typhlomolge.

A—C, the eyes of Chologaster cornutus, papilliferus and agassizii drawn to scale.

D, E, G, H, I are drawn under the same magnification.

D.—The retina of Chologaster cornutus.

E.—The retina of Chologaster papilliferus.

F.—The eye of Typhlomolge under lower magnification.

G.—The eye of Typhlichthys subterraneus.

H.—The eye of Amblyopsis spelaeus.

I.—The eye of Troglichthys rosae.

The most highly developed eye is that of Chologaster papilliferus. The parts of this eye are well proportioned, but the eye as a whole is small, measuring less than one millimeter in a specimen 55 mm. long. The proportions of this eye are symmetrically reduced if it has been derived from a fish eye of the average size, but the retina is much simpler than in such related pelagic species as Zygonectes. The simplifications in the retina have taken place between the outer nuclear and the ganglionic layers. The pigment layer has not been materially affected. These facts are exactly opposed to the supposition of Kohl, that the retina and the optic nerve are the last to be affected and that the vitreous body and the lens cease to develop early. In Chologaster papilliferus the latter parts are normal, while the retina is simplified. That the retina is affected first is proved beyond cavil by Chologaster cornutus. The vitreous body and the lens are here larger than in papilliferus, but the retina is very greatly simplified. Cornutus, it must be borne in mind, lives in the open. The eye of the cave species Chologaster agassizii differs from that of papilliferus largely in size. There is little difference in the retinas except the pigmented layer, which is about 26 per cent. thinner in agassizii than in papilliferus.

There is a big gap between the lowest eye of Chologaster and the highest eye of the blind members of the Amblyopsidae. The lens in the latter has lost its fibrous nature and is merely an ill-defined minute clump of cells scarcely distinguishable in the majority of cases. The vitreous body of the latter species is gone with perhaps a trace still remaining in Typhlichthys. With the loss of the lens and the vitreous body the eye collapsed so that the ganglionic layer formerly lining the vitreous cavity has been brought together in the center of the eye.

The layers of the retina in Typhlichthys are so well developed that could the vitreous body and lens be added to this eye it would stand on a higher plane than that of Chologaster cornutus exclusive of the cones. It is generally true that at first the thickness of the layers of the retina is increased as the result of the reduction of the lens and vitreous body and the consequent crowding of the cells of the retina, whose reduction in number does not keep pace with the reduction in the dioptric apparatus in total darkness.

If we bear in mind that no two of the eyes represented here are members of a phyletic series we may be permitted to state that from an eye like that of cornutus, but possessing scleral cartilages, both the eyes of Amblyopsis and Troglichthys have been derived and that the eye of Amblyopsis represents one of the stages through which the eye of Troglichthys passed. The eye of Amblyopsis is the eye of C. cornutus minus a vitreous body with the pupil closed and with a minute lens. The nuclear layers have gone a step further in their degeneration than in cornutus, but the greatest modification has taken place in the dioptric arrangements.

In Troglichthys even the mass of ganglionic cells present in the center of the eye as the result of the collapsing after the removal of the vitreous body has vanished. The pigmented epithelium, and in fact all the other layers, are represented by mere fragments.

The eye of Typhlichthys has degenerated along a different line. There is an almost total loss of the lens and vitreous body in an eye like that of papilliferus without an intervening stage like that of cornutus, and the pigment layer has lost its pigment, whereas in Amblyopsis it was retained.

The salamanders bridge the gap existing between the Chologasters and the blind members of the Amblyopsidae. But even at the risk of monotonous repetition I want again to call attention to the fact that the salamanders do not belong to the same series as the Amblyopsidae. The dioptric arrangements of Typhlotriton are all normal; the retina is normal in the young, but the rods and cones all disappear with the change from the larval to the adult condition. In Typhlomolge the lens and largely the vitreous body are gone and the eye has collapsed. The vitreous body is, however, much better represented than in the blind Amblyopsidae and the iris is, especially in the young, much better developed than in the fishes.

2. The retina.

(a) There is more variety in the degree of development of the pigment epithelium than in any other structure of the eye. Ritter has found that in Typhlogobius this "layer has actually increased in thickness concomitantly with the retardation in the development of the eye, or it is quite possible with the degeneration of this particular part of it. * * * An increase of pigment is an incident to the gradual diminution in functional importance and structural completeness." There is so much variation in the thickness of this layer in various fishes that not much stress can be laid on the absolute or relative thickness of the pigment in any one species as an index of degeneration. While the pigment layer is, relative to the rest of the retina, very thick in the species of Chologaster, it is found that the pigment layer of Chologaster is not much, if any, thicker than that of Zygonectes. Exception must be made for specimens of the extreme size in papilliferus and agassizii. In other words, primarily the pigment layer has retained its normal condition while the rest of the retina has been simplified, and there may even be an increase in the thickness of the layer as one of its ontogenic modifications. Whether the greater thickness of the pigment in the old Chologaster is due to degeneration or the greater length of the cones in a twilight species, I am unable to say. In Typhlichthys, which is undoubtedly derived from a Chologaster-like ancestor, no pigment is developed. The layer retains its epithelial nature and remains apparently in its embryonic condition. It may be well to call attention here to the fact that the cones are very sparingly developed, if at all, in this species. In Amblyopsis, in which the degeneration of the retina has gone further, but in which the cones are still well developed, the pigment layer is very highly developed, but not by any means uniformly so in different individuals. The pigment layer reaches its greatest point of reduction in rosae where pigment is still developed, but the layer is fragmentary, except over the distal part of the eye. We thus find a development of pigment with an imperfect layer in one case and a full developed layer without pigment in another, Typhlichthys. In the Chologasters the pigment is in part prismatic; in the other species, granular. The rods disappear before the cones.

(b) In the outer nuclear layer a complete series of steps is observable from the two-layered condition in papilliferus to the one-layered in cornutus to the undefined layer in Typhlichthys and the merging of the nuclear layer in Amblyopsis, and their occasional total absence in rosae. The rods disappear first, the cones long before their nuclei.

(c) The outer reticular layer naturally meets with the same fate as the outer nuclear layer. It is well developed in papilliferus, evident in cornutus, developed in spots in Typhlichthys, and no longer distinguishable in the other species.

(d) The layers of horizontal cells are represented in papilliferus by occasional cells; they are rarer in cornutus and beyond these have not been detected.

(e) The inner nuclear layer of bipolar and spongioblastic cells is well developed in papilliferus. In cornutus it is better developed in the young than in the older stages where it forms but a single layer of cells. There is evidently in this species an ontogenic simplification. In the remaining species it is, as mentioned above, merged with the outer nuclear layer into one layer which is occasionally absent in Troglichthys.

(f) The inner reticular layer is relatively better developed than any of the other layers, and the conclusion naturally forces itself upon one that it must contain other elements besides fibres of the bipolar and ganglionic cells, for, in Amblyopsis and Troglichthys, where the latter are very limited or absent, this layer is still well developed. Horizontal cells have only been found in the species of Chologaster.

(g) In the ganglionic layer we find again a complete series of steps from the most perfect eye to the condition found in Troglichthys. In papilliferus the cells form a complete layer one cell deep, except where the cells have given way to the optic fibre tracts which pass in among the cells instead of over them. In cornutus the cells have been so reduced in number that they are widely separated from each other. With the loss of the vitreous cavity the cells have been brought together again into a continuous layer in Typhlichthys, although there are much fewer cells than in cornutus even. The next step is the formation of a solid core of ganglionic cells, and the final step the elimination of this central core in Troglichthys, leaving but a few cells over the anterior face of the retina.

(h) Müllerian nuclei are found in all but Amblyopsis and Troglichthys. In C. cornutus they lie in part in the inner reticular and the ganglionic layer. Cells of this sort are probably also found among the ganglionic cells of Typhlichthys.

3. The optic nerve shows a clear gradation from one end of the series of fishes to the other. In Chologaster papilliferus it reaches its maximum

development. In cornutus, which possesses an eye larger than papilliferus, but in which the ganglionic layer is simplified, the nerve is measurably thinner. In Typhlichthys the nerve can be traced to the brain even in specimens 40 mm. long; i. e., in specimens which are evidently adult. In Amblyopsis the nerve can be followed to the brain in specimens 25 mm. long, but in the adult I have never been able to follow it to the brain. In Troglichthys it has become so intangible that I have not been able to trace it for any distance beyond the eye.

We thus see that the simplification or reduction in the eye is not a horizontal process. The purely supporting structure, like the scleral cartilages have been retained out of all proportion to the rest of the eye. The pigment layer has been both quantitatively and qualitatively differently affected in different species. There was primarily an increase in the thickness of this layer, and later a tendency to total loss of pigment. The degeneration has been more uniformly progressive in all the layers within the pigment layer. The only possible exception being the inner reticular layer which probably owes its retention more to its supporting than to its nervous elements. Another exception is found in the cones, but their degree of development is evidently associated with the degree of development of the pigmented layer. As long as the cones are developed the pigmented layer is well developed or vice versa.

We find, in general, that the reduction in size from the normal fish eye went hand in hand with the simplification of the retina. There was at first chiefly a reduction in the number of many times duplicated parts. Even after the condition in Chologaster papilliferus was reached the degeneration in the histological condition of the elements did not keep pace with the reduction in number (vide the eye of cornutus). The dioptric apparatus disappeared rather suddenly and the eye as a consequence collapsed with equal suddenness in those members which, long ago, took up their abode in total darkness. The eye not only collapsed, but the number of elements decreased very much. The reduction was in the horizontally repeated elements. The vertical complexity, on which the function of the retina really depends, was not greatly modified at first.

In those species which took up their abode in total darkness the degeneration in the dioptric apparatus was out of proportion to the degeneration of the retina, while in those remaining above ground the retinal structures degenerated out of proportion to the changes in the dioptric apparatus, which, according to this view, degenerates only under conditions of total disuse or total darkness, which would necessitate total disuse. This view is upheld by the conditions found in Typhlogobius, as Ritter's drawings and my own preparations show. In Typhlogobius the eye is functional in the young and remains a light-perceiving organ throughout life. The fish live under rocks between tide water (Eigenmann 90). We have here an eye in a condition of partial use, and the lens is not affected. The retina has, on the other hand, been horizontally reduced much more than in the Amblyopsidae, so that should the lens disappear, and Ritter found one specimen in which it was gone, the type of eye found in Troglichthys would be reached without passing through a stage found in Amblyopsis; it would be simply a horizontal contracting of the retina, not a collapsing of the entire eye.

The question may with propriety be asked here, Do the most degenerate eyes approach the condition of the pineal eye? It must be answered negatively.

ONTOGENIC DEGENERATION.

The developmental side of this question will be taken up with the development of the eye in Amblyopsis.

The simplification of the eye in cornutus has been mentioned in the foregoing paragraphs. It may be recalled that the nuclear layers are thinner in the old than in the young. There is here not so much an elimination or destruction of element as a simplification of the arrangements of parts, comparatively few being present to start with.

The steps in ontogenic degeneration can not be given with any degree of finality for Amblyopsis on account of the great variability of the eye in the adult. While the eyes of the very old have unquestionably degenerated, there is no means of determining what the exact condition of a given eye was at its prime. In the largest individual examined the eye was on one side a mere jumble of scarcely distinguishable cells, the pigment cells and scleral cartilages being the only things that would permit its recognition as an eye. On the other side the degree of development was better. The scleral cartilages are not affected by the degenerative processes and are the only structures that are not so affected. The fact that the eyes are undergoing ontogenic degeneration may be taken, as suggested by Kohl, that these eyes have not yet reached a condition of equilibrium with their environment or the demands made upon them by use. Furthermore, the result of the ontogenic degeneration is a type of structure below anything found in phylogeny. It is not so much a reduction of the individual parts as it is a wiping out of all parts.

PLAN AND PROCESS OF PHYLETIC DEGENERATION.

Does degeneration follow the reverse order of development, or does it follow new lines, and if so, what determines these lines?

Before discussing this point I should like to call attention to some of the processes of ontogenic development concerned in the development of the eye. There are three processes that are of importance in this connection. 1.—The multiplication of cells. 2.—The arrangement of cells, including all of the processes leading to morphogenesis. Frequently the first process continues after the second one has been in operation. 3.—Lastly, we have the growth and modification of the cells in their respective places to adapt them to the particular functions they are to subserve—histogenesis. Since the ontogenic development of the eye is supposed to follow in general lines its phyletic development, the question resolves itself into whether or not the eye is arrested at a certain stage of its development and whether this causes certain organs to be cut off from development altogether. In this sense the question has been answered in the affirmative by Kohl. Ritter, while unable to come to a definite conclusion, notes the fact that in one individual of Typhlogobius, the lens, which is phyletically a new structure, had disappeared. But this lens had probably been removed as the result of degeneration rather than through the lack of development.

Kohl supposes that in animals placed in a condition where light was shut off more or less some of the developmental processes are retarded. In successive generations earlier and earlier processes in the development of the eye are retarded and finally brought to a standstill; thus every succeeding generation developed the eye less. Total absence of light must finally prevent the entire anlage of the eye, but time, he thinks, has not been long enough to accomplish this in any vertebrate.

The cessation of development does not take place at the same time in all parts of the eye. The less important, those not essential to the perception of light, are disturbed first. The retina and the optic nerve are the last affected; the iris comes next in the series. Because the cornea, aqueous and vitreous bodies and the lens are not essential for the performance of the function of the eye, these structures cease to develop early. The processes of degeneration follow the same rate. Degeneration is brought about by the falling apart of the elements as the result of the introduction of connective tissue cells that act as wedges. Abnormal degeneration sometimes becomes manifest through the cessation of the reduction of parts (p. 269) that normally decrease in size, so that these parts in the degenerate organ are unusually large.

Kohl's theoretical explanation here given somewhat at length is based on the study of an extensive series of degenerate eyes. He has not been able to test the theory in a series of animals living actually in the condition he supposes for them, and has permitted his erroneous interpretation of the highly degenerate eye of Troglichthys to lead him to the theory of the arresting of the eye in ever earlier stages of ontogeny. The eye of Troglichthys is in an entirely different condition from that supposed by him. The mere checking of the normal morphogenic development has done absolutely nothing to bring about this condition, and it could not have been produced by the checking of development in ever earlier and earlier stages of ontogeny, for there is no stage in normal ontogeny resembling in the remotest degree the eye of Troglichthys. The process of degeneration as seen in the Amblyopsidae is in the first instance one of growing smaller and simpler (not more primitive) in the light, not a cutting off of late stages in the development in the dark. The simplified condition, it is true, appears earlier and earlier in ontogeny till it appears along the entire line of development, even in the earliest stages. The tendency for characters, added or modified at the end of ontogeny, to appear earlier and earlier in the ontogeny is well known and there is no inherent reason why an organ disappearing in the adult should not eventually disappear entirely from ontogeny. The fact that organs which have disappeared in the adult have in many instances not also disappeared in the ontogeny, and remain as so-called rudimentary organs, has received an explanation from Sedgwick. In his re-examination of the biogenetic law he came to the conclusion that "the only functionless ancestral structures, which are present in development, are those which at some time or another have been of use to the organism during its development after they have ceased to be so in the adult."

The length of time in such cases since the disuse of such an organ in the young is much shorter than that since its disuse in the adult.

All organs, functionless in the adult but functional in the early ontogeny, develop in the normal way. Organs no longer functional at any time dwindle all along the line of development. In Typhlogobius, where the eye is functional in the young, it develops in full size in the embryo, and it is not till late in life that degeneration is noticeable. In Amblyopsis, on the other hand, where the eye has not been functional at any period of ontogeny for many generations, where the eye of both young and adult lost their functions on entering the caves and where degeneration begins at an early period and continues till death, the degenerate condition has reached the early stages of the embryo. It is only during the first few hours that the eye gives promise of becoming anything more than it eventually does become. The degree of degeneration of an organ can be measured as readily by the stage in ontogeny when the degeneration becomes noticeable as by the structure in the adult. The greater the degeneration the further back in the ontogeny the degenerate condition becomes apparent, unless, as stated above, the organ is of use at some time in ontogeny. It is evident that an organ in the process of being perfected by selection may be crowded into the early stages of ontogeny by post selection. Evidently the degenerate condition is not crowded back for the same reason. How it is crowded back I am unable to say. A satisfactory explanation of this will also be a satisfactory explanation of the process by which individually acquired cnaracteristics are enabled to appear in the next generation. The facts, which are patent, have been formulated by Hyatt in his law of tachygenesis (Hyatt IX).

Cessation of development takes place only in so far as the number of cell divisions are concerned. The number of cell generations produced being continually smaller, result in an organ as a consequence also smaller. In this sense we have a cessation of development (cell division, not morphogenic development) in ever earlier stages. That there is an actual retardation of development is evident from Amblyopsis and Typhlichthys in which the eye has not reached its final form when the fish are 35 mm. long.

Histogenic development is a prolonged process and ontogenic degeneration is still operative, at least in Amblyopsis.

Degeneration in the individual is not the result of the ingrowth of connective tissue cells as far as I can determine. It is rather a process of starving, of shriveling or resorption of parts.

From the foregoing it is evident that degeneration has not proceeded in the reverse order of development; rather the older normal stages of ontogenic development have been modified into the more recent phyletic stages through which the eye has passed. The adult degenerate eye is not an arrested ontogenic stage of development but a new adaptation, and there is an attempt in ontogeny to reach the degenerate adult condition in the most direct way possible.

The Florida Gopher.

By Wm. B. Fletcher.

If there is any one animal peculiar to the United States and limited in its habits to a very small section, it is the Florida Gopher (Testudo Polyphemus (Daudin) Zerobates Carolinus Ag.), which is found in all the pine barrens and sandy uplands of Florida, and, but rarely, in parts of Alabama and Georgia; never north of the Savannah River.

The word gopher comes from the old French, and means to honeycomb, make numerous holes or burrow, and by the early French settlers was indiscriminately employed to designate all burrowing animals. To nearly all persons living outside of the three States mentioned, the word gopher indicates one of the pouched rodents, rats or squirrels which burrow in the ground and are found from Illinois west to the Pacific coast, and all over the southwestern States. What we call gophers in the North are called salamanders in the South.

Had nature intended to put into any one animal the characteristics of all that is harmless, patient, kind and non-resistent, it is found in the gopher. Possessing greater strength in proportion to its size than any of the vertebrata, yet it never attacks other animals or defends itself from them except by withdrawing its head and legs within the protection of its shell; the horny fore-arms and hands, as it were, placed over the head and face, making a complete armor against the foe, no matter how sharp the teeth or claw may be, or how powerful the jaw of the attacking animal.

The habits of the gopher are those of peace and quietude, except in the rare instances of personal contests with its kind. While it is true that they are frequently seen in numbers of ten to twenty grazing in the same locality like so many cattle, it is rare to see them close together, and there is seemingly no bond of communication between them, for the gopher is an animal of almost perfect silence and the only approach to vocal sounds is a slight hiss as the head is suddenly drawn in, compressing the lungs and forcing the air quickly through the chink of the glottis; and I have sometimes thought I recognized a faint "mew" like that of a kitten.

The gopher is a most strict vegetarian in his native State, but, under domestication, will learn to drink milk, to eat salads of various kinds, prepared with dressing of eggs, condiments, etc. He heartily abjures all kinds of flesh or insects, and would starve before eating either. He does not seem inclined to social life with his own kind, and invariably lives alone, save for the companionship—either by accident or from choice—of the white and mottled frog, or cricket, that is almost always found in his home, and which is known to the native Floridian as his "familiar." The gopher is thus an example of absolute independence, each dwelling alone in his or her own home; never have I found two in one house, and I know of none having calling acquaintances. The female deposits her eggs, from one to two dozen in number, in the sand at the entrance to her burrow, covers them up to the depth of four inches, and then her domestic duties to her family are ended; she may sit at the doorway and chew her cud when the weather is agreeable, that is, not raining, or too hot from the direct rays of the sun. She may at times cover her deposit with her impenetrable shell to keep them from the opossum or meandering coon; but one thing is certain, when the eggs are hatched by the heat of the May sun, each little gopher—an inch in diameter—goes for itself, finds its own food, makes its own house and is recognized as an independent citizen from the very shell.

When driving through the pine barrens one will sometimes pass a dozen or more of these animals grazing within a few hundred feet of one another. They swing along with heads thrust forward much as if the neck were a cable and the head the motive power, drawing a heavy inverted basin behind. Coming to a tuft of wire grass or other crisp or tender herbage they draw it in by the tongue, cut it off sharply by the triple row of sharp, serrate teeth-like edges of this horny layer of the jaws and swallow it down without mastication. The animal will give little heed to your presence or that of your dog, unless quite near his hole, but will draw himself within his shell and remain perfectly quiet for from one to five minutes, and then proceed with his journey or browsing, provided you keep still, even though you are within three feet. After feeding he returns to his abode and proceeds to masticate the coarse herbage injested. It is almost comical to see him sitting beside his doorway, his black skinny head thrust out, chewing with great satisfaction the morning's repast. It looks like a caricature of a Florida cracker sitting at the open window of his cabin chewing tobacco; but the gopher doesn't expectorate.

The average size of the full-grown gopher is twelve and one-half inches in longitudinal, and fourteen in transverse measure of the shell, the latter measurement being greater because the enameled shell bends underneath to join the plastron, or breast bone, as we might call it. When the head and legs are drawn in (the animal has no tail) from every aspect there is an arch, compressed, it is true, at the base, and, in the very old, slightly so on the top. It is from this peculiar structure that a gopher in good condition, weighing eight and one-half pounds, can lift two hundred pounds when balanced centrally. I have seen two small gophers, weighing four pounds each, attached to a cart as oxen, draw two lads weighing together one hundred and twenty pounds.

On December the third, last, I took Henry Jordan, a very intelligent native colored man, with me, and went out to get some gophers for dissection. About a mile from Palm Springs, Florida, there is a tract of country, which, eight years ago, contained most valuable orange groves, as the long rows of big dead stumps of orange trees testify. It has been abandoned and the tenantless, decaying villas, with pine and palm trees shooting up through their rotting porches and roofs, and mats of climbing roses and jasmine creeping through the open doors and windows plainly show. In these abandoned fields the gopher has taken up his habitation. On a space of ten acres I counted some fifty gopher holes. The soil is typical of Florida uplands—yellowish brown, or like white salt, is the sand through which some coarse weeds and grasses emerge in tufts. Wherever you see a pile of sand, apparently as much as two flour barrels would hold, slightly spread out in front of an arched doorway, and in that sand see the prints of the dragging shell and toe points going inward to the door, you can safely say that Mr. or Mrs. Gopher will receive callers at home.

The character of the soil or sand in which the gopher loves to delve much resembles a very light brown sugar, containing so much moisture that you may thrust your cane into it, and withdrawing, leave a hole. We find an entrance to the burrow, which has a hallway perhaps three feet wide and tapering in eighteen inches, with a downward slant to the opening proper; here we come to an arch, one-third of a circle, over a horizontal base which measures fourteen inches; we take a long rod and thrust down the incline and find it goes eight feet at an angle of forty-five degrees and then turns; we lay the rod on top of the ground in the same direction, and dig a foot or two beyond our measure, then down, and strike the hole; from this point the burrow changes direction twice, but always an easy incline downward, the sand gradually becoming more damp as we proceed. After we had made a trench some twelve feet from the entrance large enough to stand and work in, and six feet deep, I asked Henry how far he thought we must go before we got the gopher. "Well, we must jist go on dis road till we git him, if it takes a hundred yards." After digging four feet more and still down, Henry handed up a bleached cockroach, remarking, "We's most' got um; here's one of his 'familiars,' and when we come to de white frog we's got um shore." Sure enough it was so, for the spade went four feet more and we could hear it grate on the shell; at the same time a white frog jumped out. It was a bright-eyed little fellow, with transparent legs and toes. A few black specks about his head made a pretty contrast to his sparkling gold-ringed iris. "Hold on, Henry," I said, "let me pull out that gopher; I fear you will scratch him with the spade." "You can't pull him out wid an ox team," was the reply. "Well, get out of my way and I will show you; he can have no purchase in this wet sand." So in I went, "belly flat," as the boys say when coasting, squeezing myself into the hole until I got my hand on the shell. There were no hind legs to be found, and the wet oval shell was so slippery I had to give it up and be drawn out myself by the legs. "I'll show you how to get 'im widout scratchin' de shell," said Henry, and he proceeded to make a cave under the gopher. Into this he dropped, was scouped out and handed over. We had dug twenty feet, making the gopher's hole twenty-eight feet long and eight deep. In Indiana soil we would have had a half day's job to make this excavation, which, in this soft moist soil, required one hour and a quarter. The pointed, scouped spade used can be pushed into the soft sand without using the foot to propel it.

We dug out four other gophers and found there is no particular rule in the builder's mind as to how far he will tunnel or in what direction. They go into the ground for protection, for comfort and for water. A popular error exists among the natives here that the gopher does not require water because he goes only in dry places and hides from the heavy dews, or even the lightest rains; but I find that he invariably stops his digging when he has reached a sand so moist that he can suck particles of moisture through the sieve-like serrations of his jaws, which, when closed make openings of one fiftieth of an inch. If particles of sand should enter they settle in the deep groove between the serrations of the lower jaw. If you dig a little hollow six inches beyond the lower end of a gopher run you find it soon filled with water oozing up from below.

The gopher makes burrows for the purpose of regulating the temperature to a degree most fitted to his comfort and well being. When he has browsed to his satisfaction and the sun is too hot, he retires to the shade of his cave. If his shell is uncomfortably dry he retires deeper, and if he is thirsty he drinks in the filtered water from his own well. I have taken a gopher out of the ground, stopped up the entrance to his burrow, except the first foot or two, and then watched his puzzled look as he endeavored to enter. He looked curiously about as if taking in certain land marks, then, having got his bearings in mind, would make another dash at the place where his entrance had formerly been. After a half-dozen trials he threw up his head in disgust and marched off. I have put one gopher in another's hole, but it will back out and go away.

At this time I have a gopher in a little chicken coop, which has the sand for its floor. He has been there a week but has made no effort to free himself by digging out. He has buried himself all but about an inch of the rear of his shell, and from there he makes no attempt to go deeper. I have never seen two gopher holes very close together; sometimes one burrow will cross another, but never into it; the nearest being about eighteen inches.

The anatomical peculiarities of the gopher are the head, which, from the rear view, much resembles that of a frog, but is covered with a hard, black, adherent skin or scales; the jaw and tongue quite angular, looking into the mouth it seems a perfect triangle; the tongue has villi much like that of herbiverous animals; it has three well-defined stomachs. The intestine from the third stomach is very large, with muscular arrangement that the herbage injested may be brought up at will, thus the animal is able to go for weeks using up the stores of provision laid up within the large intestine. A gopher weighing six pounds had a reserve of two and one-half pounds within. I removed one and a half pounds of meat from the shell and legs, leaving the rest of his weight in the skeleton. There are forty-six laminated sections in the shell of the full-grown gopher; these laminae are about one-fortieth of an inch in thickness and readily scale off after the animal dies, leaving under each section a segment of true bone of the same shape and size. The brain of this animal (weighing six pounds) weighs but 40 grains; the spinal cord unusually large. The sympathetic and solar plexus largely developed. The heart is larger than in other testudo of like weight, having two auricles and a large, strong, half-divided ventricle. The lungs are attached to the dorsum of the thorax. The diaphragm is stronger than among the turtles. The ovaries long and broad, containing ten to twenty mature eggs, three-eighths of an inch in diameter, and perfectly spherical. When deposited they have a hard calcareous shell. In my specimen there were three hundred immature ova in the Fallopian tubes and ovaries; the tubes open into a short vaginal sheath an inch from the common outlet. The sex may be distinguished by the males having a concave form of the lower third of the sternum, while in the female it is slightly convex or flat. The upper part of the sternum (plastron) is a solid piece, projecting beyond the shell an inch and a half. The eye is covered with a nictating membrane as in birds.

The general intelligence of the gopher is quite limited. It remembers localities, but I do not think it remembers friends or enemies. I have one that has had the run of my office, house and yard for several months. It has gained in weight and is healthy. She likes a warm, snug corner by the fire when the days are cool; when outdoors she wanders about to certain places where she formerly found good pasturage. She knows where the gate is, and likes to get on the street for a promenade, where she walks on the tips of her strong fore claws; her blunt hind legs and club feet giving her the appearance of a miniature elephant.

The gopher, when turned upon the back, can not return to its natural position, and when one fights another it is to use its projecting sternum as a battering ram, striking his antagonist amidships and throwing him over on his back; then, as the vanquished foe thrusts its head and neck out to regain position, it receives various blows upon the neck from the same source. I have witnessed but one fight of this kind and that was between two female gophers. The punishment given by the larger one caused the death of the smaller one.

In evidence that there is a necessary transpiration through the under shell or plastron a gopher will die if that part of the body is vanished.

The gopher is eaten and much esteemed as food by the colored people. It is popularly supposed to contain portions of all kinds of meat and fish under its different segments. My experience is that it is more palatable than any other testudo, and it contains but one kind of meat, and that tough.

I must be pardoned for not referring to the literature of my subject. It is because I have found almost nothing, and that brief and incomplete in "Wood's Natural History," and I write this far from libraries and reference books.

Orlando, Florida, December 23, 1899.

Libraries of Microscopical Slides.

By A. J. Bigney.

Since the earliest times it has been the custom of educated people to have libraries. No line of thought has received more attention in the past few years than the biological sciences. Probably the world has received more physical good from such work than from any other source. What the next generation will bring forth can hardly be imagined. Every one who owns a microscope is adding a little to the world's stock of knowledge in biology. Not only does such a worker need books, but he should make another kind of library, a collection of slides. To the teacher in biology this is almost a necessity. To make the slides of greatest use they should be classified in some systematic way. It has been my experience and observation, in small as well as large colleges and universities, that the slides are packed away without any or very little system, and the teacher must depend upon his memory in finding them. This causes very much annoyance and much loss of time. Last fall I classified my slides in a simple way and it has been of so much value to me that I feel it is important to call the attention of other workers to this, or at least suggest something that will cause them to do the same thing.

The slide box or tray is marked with Roman numerals. The places for the slides are usually marked with the Arabic numbers by the manufacturer of the boxes. On the label of each slide are marked the Roman numeral, which indicates the number of the box in which the slide is to be placed and the Arabic number, which indicates its position in the box.

All the slides are now catalogued on cards or on sheets of paper. In cataloguing, the name of the specimen on each slide should be given and following in the Roman and Arabic numbers on that particular slide. The cards should be arranged alphabetically and kept near the slides. Since the slides are used by the different students, they will have to be replaced, and by this method any one can tell in an instant where they belong. If, for instance, you desire a section of liver, look for same on card. The reference may be XII—24; hence, find box XII, and the slide will be found at "24."

A Method of Registration for Anthropological Purposes.

By Amos W. Butler.

The Board of State Charities has undertaken a registration of the inmates of the various benevolent and correctional institutions of the State. The work began by an enumeration of the inmates of poor asylums, orphans' homes and insane hospitals, some years since, and has been elaborated so as to give the individual and family history of each person. This is now being extended to the prisons, reformatory, reform schools, school for feeble-minded youth, and institution for the education of the deaf. The information to be obtained includes the name, age, color, date of admission, physical and mental condition, together with information concerning education, home influences, religious influences, character of training, whether possessed of a trade, and other facts that are thought will have a bearing upon the individual. Family history includes the names of both parents, the place of their nativity, their pecuniary condition, whether intemperate, criminal, insane, epileptic, feeble-minded or consumptive, whether living together, or dead. It also is intended to obtain whatever collateral information is possible relating to other members of the family.

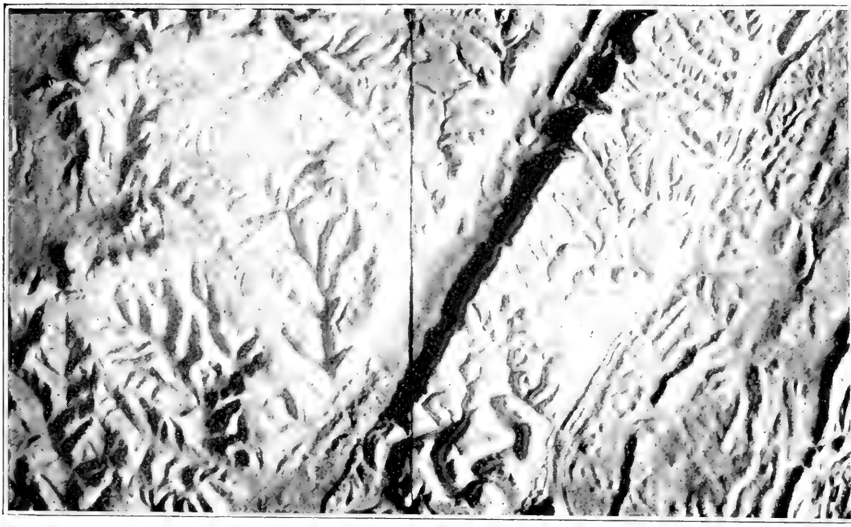
It is the purpose to extend this investigation, eventually, so that it will include the names of the inmates of all institutions coming under the supervision of the Board of State Charities. The information obtained is being registered upon cards, which are arranged after the manner of a library catalogue, so that everything known about each individual will be readily available in concise form. The purpose of this work is to learn, so far as possible, the causes of dependence and crime and the conditions under which they exist. The value of such statistics, either when one considers the case of the individual or of his descendants, can not be calculated. When fully covering the whole field and extending over a series of years, it will give the State the data from which to arrive at the most important conclusions regarding the treatment of its unfortunates and delinquents.

Aids in Teaching Physical Geography.

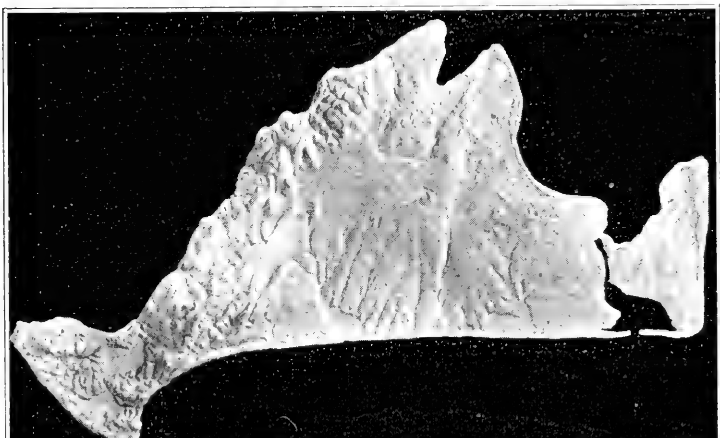
By V. F. Marsters.

For a number of years physical geography has barely received recognition in the high schools of this State. From the standpoint of accumulating useful knowledge, as well as achieving mental discipline, it is to be regretted that the subject has received so little attention. It would seem that it has been tolerated or simply permitted to exist, while the sister sciences have been fostered and developed in a manner commensurate with the means at hand. The past few years, however, have witnessed not only a remarkable advancement in geographical science, but also the introduction of new and rationalized methods in teaching the subject. The large accumulation of geographical facts accompanied by an increasing demand for rational explanation or interpretation furnishes the key to the recent interest in this subject.

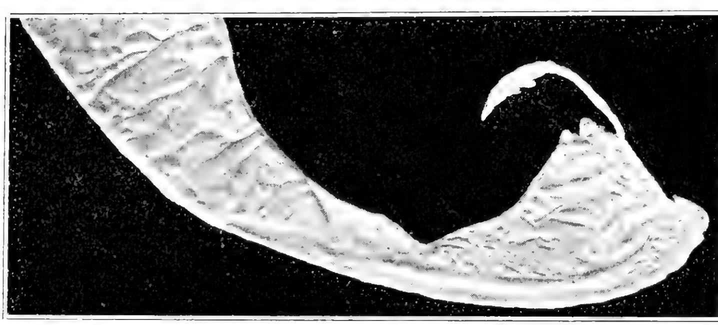
The importance of geography as an educative science must be conceeded when it is known that the most progressive universities have



Sewanee Model. Chattanooga Model.



Martha's Vineyard.



Cape Cod Model.

placed the subject on an equal footing with the other sciences which have for years found a respected place in the college curriculum. That this fact is being recognized beyond the walls of the university must be admitted when we see a number of the larger cities of the country employing specialists to instruct their teaching force and familiarize them with a rational method of teaching. I am informed that the city of Indianapolis has employed a well-trained man for this specific purpose. This is a step taken in the right direction. Moreover, about all the commissioned high schools of the State have placed physical geography on the schedule of studies, although in many cases but a short period is devoted to the subject. These facts point to the conclusion that physical geography has gained a deserved place in the public schools, and, moreover, with due recognition, it is destined to play as important a role as any of its allies as an educative science because of its recognized disciplinary value.

Let us look for a moment at some of the recent methods of teaching the subject. Ten years ago it was all sufficient for the student to describe a geographical element, or simply to accumulate facts. If the student knew all the capes on the Atlantic and Pacific coasts and their locations, nothing more was to be learned about them. The question was not asked why any geographical element should appear here or there, why this or that territorial limit of topographical expression should exist; it was sufficient to be able to know the fact of its existence, location and general features without calling for an explanation. Such knowledge is empirical. The serious student is no longer satisfied with empirical description, but he demands explanatory description. It is in this particular phase that marked advancement has been made. Empirical description is rapidly giving way to rational explanation of geographical phenomena. The absence of an educative discipline in the former, and its necessary inherence in the latter, fully accounts for the recent growth of the so-called new geography. Thus, rational geography demands not only the *collection of facts* by personal observation, but it also calls for an *explanation* of the *observed facts*; such a process must employ comparison and deduction. Moreover, the conclusions reached or the method of explanation derived by comparison and deduction must explain not only all the facts at hand, but they must also account for many other related facts yet to be collected. It is only by the employment of these broad and fundamental principles that the accumulation of useful knowledge and, above all, a valuable mental discipline can be attained.

There are many aids towards this end. It is, however, only within recent years that much of this material so useful to the geologist, as well as to the geographer, has come within the reach of the secondary schools. The apparatus, which should be found to some extent at least in all schools and colleges purporting to teach geography, may be described under the following headings:

1. Photographs and lantern slides.
2. Maps.
3. Models.

1. Photographs.—The collections of photographs, made by the usual dealers, furnish very little material that has any special geographical significance. Such collections are usually made with reference to depicting some artistic expression in a landscape, and invariably fail to bring out such topographic outlines as would be of significance to the student of geography. A fairly useful selection can be made from a collection made by various members of the Geological Society of America, and placed in the hands of a committee for classification and distribution. Further information may be obtained by applying to G. P. Merrill, Washington, D. C., or to Prof. F. L Fairchild, Rochester, N. Y.

Lantern slides are even more useful than photographs because they present a more vivid picture, and details more easily discerned. Moreover, the relation of parts are more clearly brought out because of the enlargement; in fact, it is the next best to seeing the actual thing illustrated. In the use of the lantern, however, care should be taken not to introduce this method of illustration as simply a species of entertainment, but rather as an essential part of the course to be absorbed by the student as well as text or lecture.

What has been said of the insufficiency of the dealers' photograph collections is equally true of their lantern-slide collections. An examination of the stock of a number of dealers furnished but little useful material. This long-felt want has in part been supplied by Prof. W. M. Davis, who has made a very excellent collection of about one hundred and fifty slides, illustrating the prominent and essential features of the forms of the land, rivers, lakes, glaciers, shorelines, waves, etc. The entire collection may be obtained from E. E. Howells, Washington, D. C.

In the interest of Indiana geography, it is proposed to make a collection of photographs and lantern slides during the coming year, which may illustrate the most common and prominent topographic features of the State. It would, of course, be desirable to have both series in the schools, but when the purchase of a lantern is not possible, photographs, of course, may be substituted. It is hoped that such a collection of laboratory material may create and stimulate further interest in the subject and help to place it on an equal footing with the other observational sciences observed in the school system.

Maps.—There are a number of sources from which many selections of useful illustrations of topographic types may be obtained. The United States Geological Survey has prepared a large number of topographical and geological sheets covering portions of the United States. It is to be regretted that this national organization has not published a single sheet covering any portion of the State of Indiana. A part of this neglected work is being done by the Geological Department of Indiana University. In addition to the series of sheets mentioned above, the National Survey has lately prepared a large number of folios, forming a part of the "Geologic Atlas of the United States." These have been made to serve educational purposes in particular, but strange as it may seem, a large number of the best equipped high schools of the State have failed to make use of the opportunities offered. The folios contain a topographic sheet, a second showing the areal geology, a third illustrating the geology in cross section, and sometimes a fourth devoted to the economic geology. Each folio is accompanied with an explanatory text.

From the United States Coast and Geodetic Survey may be obtained a series of maps giving the minutest details of shore-line topography. For a list of the maps address this department at Washington, D. C.

It is gratifying to learn that in a few of the high schools of this State the daily weather maps are being used with a considerable degree of success. These may be obtained by addressing the local forecast official, C. F. R. Wappenhans, Majestic Building, Indianapolis.

Another source for information of meteorological interest is the United States Hydrographic Department, which issues each month a series of pilot charts of the North Atlantic and North Pacific oceans. On these charts are shown the storm tracks, the date of their occurrence and the direction of their course (from which can be determined their rate of movement), calms and prevailing winds, derelicts and wrecks, icebergs and field ice, regions of frequent fog, etc.

The most available source for information on all these publications, and offering assistance in the selection of types from each group, is a little manual entitled "The Use of Governmental Maps in Schools," by Messrs. Davis, King & Collie, and published by Henry Holt & Company, New York.

For information concerning foreign maps, the teacher is advised to consult an article by Prof. W. M. Davis on "Large Scale Maps for Geographic Illustrations," published in the Journal of Geology. A reprint of this article may possibly be obtained by addressing Prof. T. C. Chamberlain, Chicago University.

Models.—One of the most novel and still most effective means in the teaching of geography as well as geology, is supplied by models illustrating the topographic form and the rock structure upon which the topography is made.

Models are of two kinds: One may represent the actual topography of a surveyed section of country and the other may be an idealized land form, depicting the essential and expectable features. The latter may be called "types of land form." Of all the materials mentioned, as forming equipment for a geographical laboratory, models may be regarded as of special value. It is indeed unfortunate that the cost of models in general is so excessive that a large number of the secondary schools may not be able to purchase the larger and most expensive illustrations of land forms, but still there are many that come within the reach of schools with but meagre appropriations.

During the past year the Department of Geology and Geography, Indiana University, has given a course in physiographic geology. Practice in the construction of relief maps may be taken as part of the laboratory work required in the course. It is of course evident that a knowledge of the various methods of making relief maps is of great advantage to the teacher who may be called upon to accumulate material for a geographical laboratory. As a result of this course, the following relief maps have been constructed, the data having been obtained from the topographic and the geologic atlas sheets, published by the United States Geological Survey:

Chattanooga and Sewanee Sheets, Tennessee, horizontal scale, 1″=1 mile; vertical scale, 1″=1,600 feet.

Harper's Ferry Sheet, Baltimore, Md., horizontal scale, 1″=1 mile; vertical scale, 1″=1,600 feet.

Martha's Vineyard Sheet, horizontal scale, 1″=1 mile; vertical scale, 1″=400 feet.

Cape Cod, horizontal scale, 1″=1.5 miles; vertical scale, 1″=600 feet.

Amsterdam Sheet,* New York, horizontal scale, 1″=1 mile; vertical scale, 1″=1,000 feet.

The following models are in process of construction: Boston Harbor Sheet, Mass., and the Sun Prairie Sheet, Wisconsin. These models will show some very excellent types of glacial topography. The completed series of models illustrate some of the most common and conspicuous types of topography and geological structure. It is, indeed, just the kind of material that should be found in the laboratories of the secondary schools. In order that some assistance may be given in this direction, the geological department has preserved the negatives of the models mentioned. From these any number of positives may be prepared; and it is proposed to supply copies of one or more of these to any high school desiring to establish a geographical laboratory. Copies will be sold at the cost of construction, so that the school with but meagre appropriations can at least make a beginning by adding one model each year to the laboratory equipment. It is hoped that the high schools of the State will not be slow in taking advantage of the opportunity here offered. Effective work in geography can not be done without a laboratory; and of the kinds of available material mentioned, maps and models should form a prominent part of the equipment. The writer will gladly correspond with any one desiring further information.

Geological Laboratory, Indiana University.

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*Constructed by E. R. Cumings, Instructor in the Department of Geology, Indiana University.

Some Preliminary Notes on the Hygienic Value of Various Street Pavements as Determined by Bacteriological Analyses.

By Severance Burrage and D. B. Luten.

In many of our large cities, and small ones, too, the question of pavement is a very important one. The government looks largely upon the question of economy, the life of the particular pavement being perhaps the most important factor in assisting them to a decision for or against it. Some pavement companies in pushing their own work, will claim that their pavement is more sanitary than this or that one. Have they any data, any facts that will permit them to make such statements? It was partly for the purpose of settling this question that the foregoing experiments were undertaken.

In working on this subject, it has been found that the sanitary or hygienic value of a pavement depends almost entirely on its power to collect, retain or give up dust, although there are other factors, such as reflection of heat, etc., that must be considered. But this dust leads to a discussion of the point as to whether a strictly sanitary pavement is one that will remain moist the longest time, thus holding on to the dust, and at the same time, perhaps, permitting the multiplication of bacteria; or whether the sanitary pavement is the one that dries the quickest, and with the assistance of traffic and the winds, scatters the dried dust broadcast.

Street dust is always laden with bacteria, and it was thought that possibly some bacteriological analyses under different conditions might assist in the solution of this problem. It is not necessary to state that aside from the bacterial contents of dust, hygienically speaking, it in itself is an irritating factor to the mucous membrane of the nose and throat, as well as to the delicate membranes of the eye. And thus, without taking the bacteria into account at all, the pavement permitting the least dust would be regarded as most sanitary. But the bacteria usually occur in proportion to the amount of other dust, so the measure for one will serve fairly well as an indicator for the amount of inorganic dust. The experiments herein reported were undertaken on the Lafayette, Indiana, pavements, including macadam, brick, wood block (not creosoted), and sheet asphalt.

There is almost no reliable literature on the subject, and what little there is seems to universally condemn the uncreosoted wood block pavement.

From Byrnes Highway Construction, 1893, Dr. O. W. Wight, Health Officer of Detroit, in a report to city council, says: "On sanitary grounds, therefore, I must earnestly protest against the use of wooden block pavements. Such blocks, laid endwise, not only absorb water which dissolves out the albuminous matter that acts as a putrefaction leaven, but also absorbs an infusion of horse manure, and a great quantity of horse urine dropped in the streets. The lower ends, resting on boards, clay or sand, soon become covered with an abundant fungoid growth, thoroughly saturated with albuminous extract and the excreta of animals in a liquid putrescible form. These wooden pavements undergo a decomposition in the warm season and add to the unwholesomeness of the city. The street in fact might as well be covered a foot deep with rotting barnyard manure so far as unwholesomeness is concerned. Moreover, the interstices between the blocks and the perforations of decay allow the foul liquids of the surface to flow through, supersaturating the earth beneath and constantly adding to the putrefying mass."

M. Foussagrivs, professor of hygiene, at Montpelier, France, objects to wooden pavements because they "consist of a porous substance capable of absorbing organic matter, and by its own decomposition giving rise to noxious miasma which, proceeding from so large a surface, can not be regarded as insignificant. I am convinced that a city with a damp climate, paved entirely with wood, would become a city of marsh fever."

An article by Amat in the Bull. Gen. de Therapeut, is of some interest in this connection. He compares the advantages and disadvantages of wood pavement with those of granite blocks and asphalt. In regard to cleanliness he places then in the order of merit—asphalt, granite, wood. In regard to quiet—wood asphalt, granite. In regard to cheapness—granite, wood, asphalt. Durability__granite, asphalt, wood. Ease of repair—asphalt, wood, granite, and safety—wood, asphalt, granite.

Miguel tested bacteriologically some ten-year-old wood pavements, and found from a million to a million and a half germs in a gram of sawdust from the surface, and from five hundred to four thousand in a gram of the sawdust taken two inches below the surface. These same experiments were repeated by Rolst and Nicoles, giving the same relative results, but the numbers of bacteria being twenty times as large.

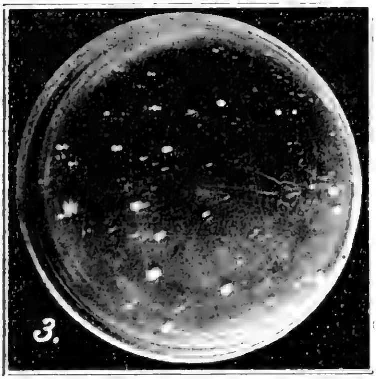
Professor Brown, of Yale College, says that "even in the free air and full sunlight, along with the putrescence, a white fungous growth begins on the surface of the wood, which rapidly becomes slimy. This forms much more rapidly on the ends of the grain of the wood than on the radial or tangential sides. The fungous growth goes on, modified of course by the temperature and the degrees of concentration and it continues for an unknown period, or until decay has become complete. Heartwood and sapwood act alike in this matter; the difference is one of degree rather than character."

The Legislature of New South Wales (Australia) appointed a board to "inquire into the alleged deleterious effects of wood pavements upon the public health. The board examined specimens of wood pavements as laid in the city of Sidney, taking up blocks at different points. In all cases the concrete bed underneath was moist; in three cases a large amount of slimy mud was found, giving off an ammoniacal odor. The blocks were chemically examined to determine whether they had absorbed organic matter, with the result that some were found impregnated with filth to the very center, while others were comparatively free from it. The board comes to the conclusion that wood is a material which can not safely be used for paving unless it can be rendered absolutely impermeable to moisture. * * * So far as the careful researches of the board go, the porous, absorbent and destructible nature of wood must, in its opinion, be declared to be irremediable by any process at present known; nor were any such processes discovered, would it be effectual unless it were supplemented by another which should prevent fraying of the fibers. Still less can the defects of wood be considered of less consequence than the defects of other kinds of materials. * * * Your board therefore recommends that the paving of the streets of this city with wood should be discontinued, and desires to add that this recommendation is extended to apply not to the particular mode of construction here adopted alone, but to the material itself and to every known method of construction."

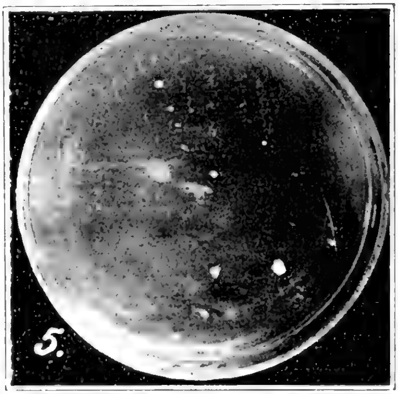
On the other hand, a comparison of the death rate in cities using wood pavements with that in cities where little or no wood is employed seems to show that wood pavements do not cause an increase in the death rate, i. e.:

Macadam.

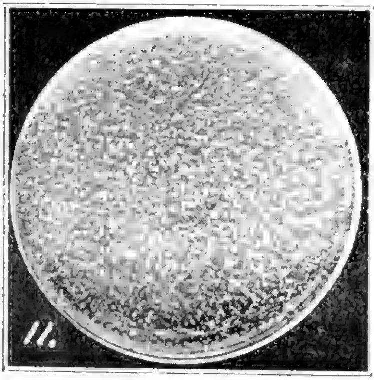
Sheet Asphalt.



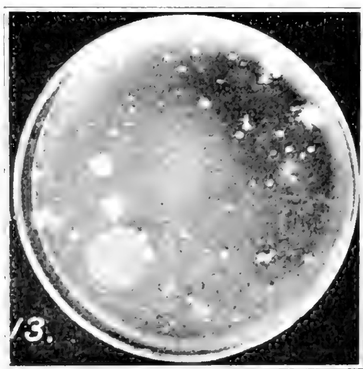
Wood Block.



Brick.



Sheet Asphalt.



Brick.

City.	Death-rate.	Percentage of Wooden Pavements.
New York	25.19	0
Boston	23.06	0
Philadelphia	19.74	0
Nashville	23.70	0
Atlanta	19.87	0
Milwaukee	16.90	48
Chicago	17.48	80
Detroit	14.70	91
Duluth	99.17	95

If there were not so many other conditions this might be convincing in favor of wood block. All these data were collected about 1890.

Fig. 1.

The two latest books on pavements (1893 and 1894) contain nothing better. As far as technical journals are concerned, the matter seems to be considered satisfactorily settled by such arguments as the preceding; no further investigations along these lines seem to have been made.

METHODS OF ANALYZING AIR OF PAVEMENTS FOR BACTERIA.

The bacteriological examinations were carried on by means of using the agar plate exposure, four-inch Pasteur dishes being used. These agar plates were exposed (always in duplicates) on an ordinary surveyor's tripod, as shown in Fig. 1. This made the exposure about five feet above the pavement. Half way between the exposed plates and the pavement hung the anemometer, which had to be used to determine differences in wind velocities from minute to minute. These plates were always exposed for exactly ten minutes, and careful notice taken of the amount of traffic, direction of wind, and anything that would affect the amount of floating dust. Great care was taken to see that the wind was blowing as nearly parallel to the street as possible, so that the analysis would surely be of the street dust, and not of the dust from the adjoining lots.

One set of exposures was made between 12 and 2 o'clock at night when the life on the streets would be at a minimum. The results of this set of plates were as follows, the numbers indicating the number of bacterial colonies on each agar plate that had had an exposure of ten minutes:

Wood block (uncreosoted), Plate No. 3	50
Brick, Plate No. 5	16
Sheet asphalt, Plate No. 2	14½
Macadam, Plate No. 1	9½

The numbers indicate the average number of bacterial colonies on the two plates that were exposed side by side over each pavement.

Another interesting set of exposures was made at a time when the macadam street was muddy, the brick pavement was fairly dry, except for moisture in the interstices, and the sheet asphalt was dry. A drizzling rain had occurred about twenty-four hours previous to the exposure. Results as follows:

Sheet asphalt, Plate No. 11	2850
Macadam	147
Brick, Plate No. 13	99

In this exposure it was evident that the sheet asphalt pavement had become quite dry and the dust was stirred up to a very considerable degree by the passing traffic, fifty-three carriages, two bicycles and one horseback going by during the ten minutes' exposure. The wind was very light.

Another exposure was made when everything was dry, and after the wind had been strong and gusty for some hours, with the following results:

Macadam	958
Brick	463
Wood block (uncreosoted)	304
Sheet asphalt	180

Here the sheet asphalt had apparently been wind-swept, and was clean and dry.

The averages of all exposures, excluding the midnight one, were as follows:

Macadam	1386
Sheet asphalt	1084
Brick	960
Wood (uncreosoted)	361

Therefore, if the amount of dust floating over any given pavement is a measure of the sanitary value, these pavements in question will take the following rank: wood, brick, sheet asphalt and macadam. The above averages include exposures under all kinds of varying conditions.

While we do not feel that we can conclude anything very definite from these experiments, they seem to point to possible conclusions of value if pursued to the proper extent. Previous opinions commending or condemning any pavement from the sanitary standpoint lack scientific foundation, and therefore are not to be seriously considered. In the experiments herein reported there are a number of factors that need to be more carefully determined, such as, that the bacteria that are caught on the agar plates actually come from the pavement and not from the surrounding lots and buildings; and furthermore, that these bacteria are of a pathogenic nature or not. These uncertain features are receiving careful attention in our future experiments, and it is hoped that in their study will be found the key to the solution of these pavement problems.

Insects as Factors in the Spread of Bacterial Diseases.

By Severance Burrage.

From the earliest times theories have been advanced relative to the spread of disease by insects. Just what part the insect played of course was unknown, and naturally must have remained unknown until the discovery of bacteria and their relations to diseases firmly established. But since the germ theory has been established the subject of insects and disease has received much attention, although not all that it may have deserved. The bibliography on the subject, collected by Dr. George H. F. Nuttall, numbers nearly four hundred papers and articles, many of them representing exhaustive experimental work, and others are of general interest, and of practical value.

Books on hygiene and sanitary science, even the latest editions, do not mention insects as disease-spreading factors, yet they go into detailed discussions of many less important subjects. Undoubtedly many epidemics of contagious and infectious diseases have been caused directly or indirectly by insects, and then laid at the door of the water supply, infected food, or bad drainage. While water or milk may have been the immediate means of spreading the disease among large numbers of individuals, *one* insect may have caused the infection of the water or the milk.

As a disease carrier, we must regard an insect in one of two classes. He may be either the simple carrier of the bacteria, transporting the germs of disease on or in his body from an infected person to some healthy person's environment, the bacteria being wiped off from the insect's body or deposited in his excreta on the food or clothing of the susceptible healthy person; or the insect may be an intermediate host, in which the parasite or germ undergoes a part of its life cycle, and then the germ is transmitted to the healthy individual through the sting of the insect, the insect's fang acting as the inoculating needle.

In the latter class the mosquito and cattle tick are the best known, the mosquito carrying the malarial plasmodium, and the tick the organism of Texan cattle fever. Notwithstanding the importance of these diseases from the hygienic standpoint, they do not come under the head of bacterial diseases, as they are caused by animal parasites. It would, perhaps, be well to mention, however, in passing, that the theory connecting mosquitoes and malaria has been established beyond a doubt. More research work has been done in this connection than along any other line of the subject.

While not overlooking the importance of the mosquito theory, this paper must deal more with the strictly bacterial diseases.

HISTORICAL.

We are indebted to Dr. G. H. F. Nuttall, M. D., Ph. D., of Johns Hopkins Hospital, for collecting the facts along these lines and publishing them in one pamphlet.[1] There is much literature quoted on anthrax and its connection with various insects, particularly the fly. There are but few positive cases recorded, although scientists do not hesitate to say that insects probably do play an important part. Experimental work was carried on with anthrax and biting flies in 1869 and 1870, independently, by Rainbert and Davaine.

The bodies and the proboscides of the flies, such as tabanus, haematopota and stomoxys, were infected with anthrax material, and after a definite time, such as two, twelve or twenty-four hours, parts of these infected animals were inoculated into healthy animals. In nearly all cases of this kind the animals died of anthrax.

Railliet sums up these and other experiments with anthrax and biting flies by saying that it is conceivable that the proboscides of stomoxys and similar flies may inoculate septic organisms, having previously become contaminated on cadavers or diseased animals; "nevertheless no direct proof has been given as yet in favor of this view." Nuttall goes on to say that it seems "perfectly absurd that any value should have been attached to such experiments. When the insect sucks blood it injects uninfected saliva, and sucks up the bacteria that may adhere to its proboscis; and while it is conceivable that infection may occur, it is more probable, when we consider the process, that infection is the exception and not the rule."

Some forms of beetles are supposed to have been active agents in spreading anthrax. Proust and Hien made examinations of skins that had been supposed to cause anthrax in persons handling them. Living dermestes vulpines and various larvae were found. All the living insects were found to have spores of anthrax on their bodies and in their excreta.

Nuttall carried on a valuable series of experiments with the bed bug

[1] Johns Hopkins Hospital Reports, Vol. VIII, Nos. 1 and 2, Baltimore, Md.

and flea and anthrax, but all his experiments gave negative results, and he concludes that "infection through the bite of a bed bug either does not occur or is exceptional; and further, that infection might occur if this bug were crushed, and the part scratched, is self-evident." And in regard to fleas, the anthrax bacilli die off rapidly in them, and the conclusion appears justified that they can not play much of a rôle, if any, in the spread of this disease.

The plague is supposed to be spread in some measure by means of flies and other insects. Nuttall's conclusions, as far as the biting insects are concerned, are the same as under anthrax, namely, that infection through their bites is exceptional and not the rule, but, "on the other hand, it is quite possible that a person crushing an infected bug, and scratching the spot where the insect has bitten, may thus inoculate himself with the plague bacillus. This, however, would not take place if a sufficient interval of time had elapsed after the bug had sucked blood containing the bacilli."

But Nuttall's experiments with flies infected with the plague bacilli, by which he determined that infected flies could live for several days, point to the possibility as he rightly concludes, that they play no inconsiderable role in the spread of the plague, for they have plenty of opportunities to gain access to food into which they might fall and die, or on which, in again feeding, they would deposit their excreta laden with plague bacilli.

Nuttall was satisfied that the flies themselves could die of the plague. A few experiments are recorded with hog erysipelas, mouse septicaemia, recurrent fever, chicken cholera, and yellow fever, which result in very positive conclusions. Experimental and other evidence points conclusively, however, that Asiatic cholera is disseminated by flies. Tuberculosis and leprosy are undoubtedly spread in this way.

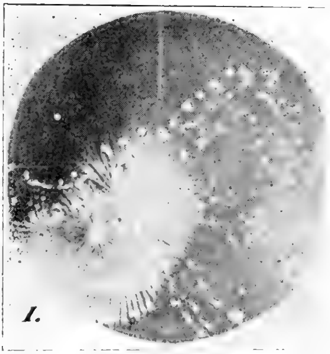
Particular attention was called, during the recent war with Spain, to the spread of typhoid fever through our camps. In fact, it was well demonstrated that the fly played a most important part in the spread of disease throughout the camps, making due allowance for the other factors, such as poor food and bad water. All the conditions about the camps seemed to favor the fly in his dirty work. Flies are attracted alike to food material and to filth. Fecal matters, fresh from the bowels of typhoid patients, and oftentimes without even an apology for disinfection, lay exposed in open trenches, and in sultry weather millions upon millions of flies swarmed on and about this material.

Short distances away from these trenches were the cooking and dining tents, and between these two sources of fly attraction the insects were continually passing. Thus it was made only too easy for the flies to transfer infectious material from the trenches to the food; and as much of the food is not cooked at all, there is no chance for the germs to be killed.

To show the condition of affairs in the camps, as described by an eye witness, I will quote from a letter of Dr. I. W. Heysinger, of Philadelphia, to one of the medical journals: "In the hospitals, the vessels used by the patients beside their beds, were black with them (flies), and they only disappeared when the dinners were brought along, and the attendants went back to the cook house to chase off the invading inhabitants there, and bring up milk to complete the menu. The open sinks are also black with these buzzing scavengers, which rise in clouds when the surface is disturbed, and their feet loaded with fecal debris rise to seek new pastures at breakfast, dinner and supper and all through the day, intermittently around the cook house.

"Into these sinks go the discharges of the typhoid patients, and pathogenic bacteria that can not make an effective culture there on a most majestic scale are 'simply not in it.'

"Can anyone wonder that a single case of typhoid will thus infect a a whole camp and increase the virulence of a mild case to the point of a necessarily mortal result? Ingenuity could not devise any plan so simple, so efficacious and so widespread as this for scattering a pestilence. Every fly leg is good for a large number of almost any required sort of pathogenic bacilli, and some flies are nearly all legs, and the rest snout and wings, which also play their part with regularity and despatch." Dr. M. A. Veeder, of Lyons, N. Y., describes the conditions around a private house. He says: "Even in a private house, not at all uncleanly, I have seen typhoid dejections emptied from a commode, and the latter thoughtlessly left standing, without disinfection, within a few feet of a pitcher of milk just left at the door, both the commode and the pitcher attracting the flies, which swarmed about and went from one to the other. Is it strange that there were numerous cases of the disease in that house, and in the house next to it? I have seen a shallow, old-fashioned water-closet fairly buzzing with flies on a hot day, and all around it open win-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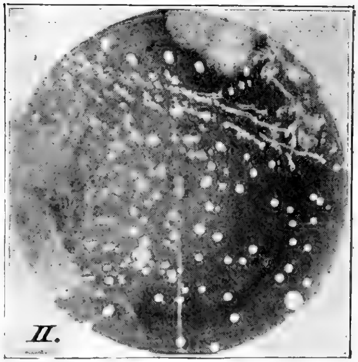
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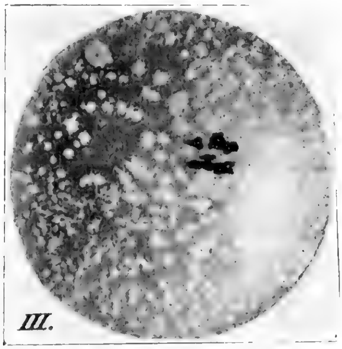
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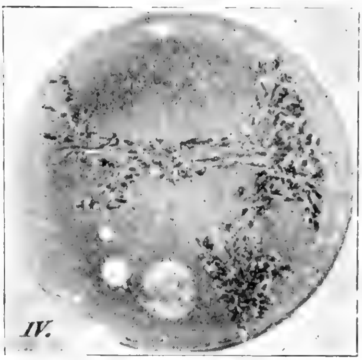
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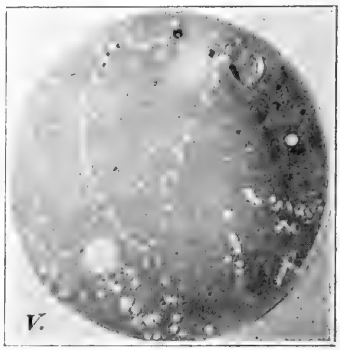

V.

dows and doors leading into kitchens, pantries and dining rooms. A single case of typhoid would start a severe local epidemic under such conditions."

Summer work in a bacteriological laboratory would convince anyone of the flies' liking for pathologic material of any kind. They are sure to light near and crawl over slides being prepared for stains, which makes it necessary to cover everything with bell-jars to prevent laboratory infection. Moreover, flies are always more attracted toward diseased persons than toward the healthy ones.

The whole subject is of great interest to the sanitarian, because it opens up a comparatively new field in preventive medicine. It applies to the home as well as to the community in regard to general cleanliness and methods of garbage disposal.

STRUCTURE OF HOUSE FLY.

Any one who has examined the fly's foot under the miscroscope can not fail to see how perfectly it is constructed for the retention of dirt and filth. The fine hairs and the suctorial discs afford magnificent opportunities for infectious material to be lodged in and thus transported from one spot to another. In fact, in making a microscopical examination of several flies' feet for the purpose of making a photograph, it was next to impossible to find one that did not have considerable dirt attached to it.

The proboscis of the fly also affords an excellent resting place for dirt of any kind, and the wings and body also serve to retain material. Thus the fly seems to be made for the purpose of carrying small quantities of dirt around with him all the time, a circumstance that is quite alarming if we could follow in the wake of the fly in his daily and hourly travels, instances of which have been cited above.

LABORATORY WORK.

While laboratory experiments are not always satisfactory in a subject of this kind, yet I take the liberty of describing here some that were undertaken in the Purdue laboratories during the past year. While the experiments, in part at least, have been done in other laboratories, the results obtained here were very satisfactory, and the plates were so well marked that I deem them well worth the attention of the Academy.

Experiment No. 1. Typhoid Fever and Fly.—The fly was placed under the bell-jar with filter paper saturated with fresh boullion culture of B. typhi abdom., twenty-four hours old. The fly was closely watched, and after he had been observed to walk over the filter paper several times, the bell-jar was carefully moved from the filter paper. After twenty minutes had passed, a Petri plate containing a thin film of sterile agar was placed under the jar, and the fly again watched. He did not seem to be attracted to the agar, and after waiting perhaps half an hour, it was decided to force the fly to walk over the agar film. So he was carefully caught between the agar film and the Petri dish cover, and he then walked over the agar beautifully. The agar plate was incubated for twenty-four hours and the result was very significant. It is shown on plate No. 1, on which the clearly defined fly path, marked by bacteria colonies, is clearly shown. A further examination determined the presence in these colonies of the typhoid bacilli.

Experiment No. 2.—A similar experiment with some filter paper, saturated with typhoid fever, using another fly, somewhat less time elapsing between his inoculation, and being made to walk over the agar. This fly did not enjoy walking on the agar and jumped around over the plate considerably, as shown by the large number of colonies; plate II. Once or twice he made a fairly straight track, however, as may be seen. These colonies were also proved to contain typhoid fever.

Experiment No. 3. Prodigiosus.—Large fly. After one-half hour walked over gelatine; too lively to make tracks; infected whole plate; plate III.

Experiment No. 4. Prodigiosus.—Fly's wings removed, and then he was allowed to walk over infected paper and agar plate; plate IV.

Experiment No. 5. Prodigiosus.—After eighteen hours fly, that had been infected with prodigiosus, was allowed to walk over plate; plate V.

CONCLUSIONS.

It is evident that the fly can become infected with bacterial filth and hold on to it for sufficient time to inoculate food materials or other materials surrounding human lives. They must always be regarded as a menace to health as long as they have access to filth in the neighborhood of human dwellings, be they temporary or permanent. All evidence points to the strong need of disinfecting or destroying all the wastes from ourselves and other animals, destroying all excreta in which the flies deposit their eggs, and to do all to eliminate this factor in the spread of infectious and contagious diseases that heretofore has received so little attention.

House Boats for Biological Work.

By Ulysses O. Cox.

House boats for pleasure are not at all uncommon on the Mississippi River, but one built and equipped for scientific purposes was, until the past summer, entirely unknown on that stream, and, I am told, on most streams in this section of the country. Last March the writer was called to Minneapolis by the director of the State Zoological Survey, Professor Nachtrieb, and asked to suggest plans for further study of the fishes of the State. Among these suggestions was the one that a house boat, or rather, in this case, a floating laboratory, be built at Mankato to float down the Minnesota and Mississippi rivers, at least as far as the State line.

There were a number of things to be taken into consideration. It had been several years since the Minnesota River had been navigated by any craft larger than a row boat, and just how large the floating laboratory could be made and still float and be manageable was a question. There were numerous bridges to pass, many sand and gravel bars to interfere and hundreds of snags to be avoided. It was finally decided to build the barge portion of the boat twelve feet wide, twenty-two feet long, two feet deep and with a flat bottom. It was estimated that a boat so built would draw, when empty, no more than five or six inches of water, which estimate proved later to be correct. On top of the barge was built a cabin twelve feet wide, fourteen feet long and six and one-half feet high. The roof of the cabin was covered with boards and then with canvas. At each end of the cabin a door opened out on the platform, which was as long as the width of the boat, and four feet wide. On each side of the cabin there were two long, movable windows. In one corner of the cabin there was a well equipped dark room for photographic work. Along one side of the room was a laboratory table fitted with drawers and shelves, and in another part were numerous shelves for specimen jars and dishes. A common cooking stove adorned one corner of the room, and in the floor were two large galvanized-iron tanks in which eatables were stored. Besides a complete cooking outfit, cots and bedding, we had various kinds of seines, gill nets, hooks and lines, microscopes, dissecting tools, injecting apparatus, and all other things needed for preserving any material that we might find. Besides a large number of jars and bottles, two large galvanized-iron tanks served for storing preserved material. Formalin was used altogether for preserving museum and anatomical material, and it worked exceedingly well, except when left in the sun. Under the latter conditions, the formalin seemed to decompose and the material would spoil.

We guided our boat, which we named "Megalops," by means of two large oars that worked in oar locks placed on each end of the boat, and we found no difficulty whatever in directing the boat just where we wished, except when the wind was blowing. At such times it was frequently necessary to anchor until the wind ceased. Our speed was seldom rapid, but it was usually very satisfactory. We would move a mile or so and then probably stop a day or two to investigate the ground, and would remain at one place as long as the collecting was profitable. During the four months we were out we traveled from Mankato on the Minnesota River to Red Wing on the Mississippi, and did not meet with a single accident of any consequence. It will be remembered, also, that much of this distance is frequented by steamboats, rafts and floating logs.

At times there were as many as six persons in the party, but usually only five. During the four months that the Megalops was in commission, the following persons were on her for work: Prof. H. F. Nachtrieb, of the State University of Minnesota, and Chief of the Zoological Survey; Dr. D. T. McDougal, of the Bronx Park Botanical Gardens, New York City; Dr. W. S. Nickerson, of the Minnesota State University Medical School; W. S. Kienholtz, J. E. Guthrie, and Charles Zeleny, students of the University; George Hinton, the "boy" and "cookee," and the writer, who was dubbed the "captain."

In every way the trip was a success. We discovered a number of what may prove to be new species of fishes, certainly new to Minnesota; collected a great many insects, some of them new, and a number of reptiles. Besides these, extensive data were secured concerning a number of fishes, valuable histological and embryological material was preserved, and a number of anatomical preparations were made. There is no better way, it seems to me, to study the fauna and flora of a river than by such a floating laboratory, and I wish to strongly commend the plan to any persons who are considering plans for such study.

The Megalops now lies anchored at Red Wing Minnesota, on the Mississippi River, and it will likely continue on down the river the coming season, after which it may become a part of the equipment of a permanent biological laboratory on the Mississippi, which it is hoped will soon be established by the University of Minnesota.

Tests on Some Ball and Roller Bearings.

By M. J. Golden.

These tests were made to determine the comparative friction of ball and roller bearings when used for shafts under ordinary shop conditions, so the simplest forms obtainable were used, and they were tested at such speeds as usually occur in shop practice. When used in shop practice two or more of these bearings are placed side by side and in this way an ordinary hanger or other such piece of apparatus is built up. In the test the unit of the maker was taken for the size tested and no effort was made to establish any relation as to comparative sizes.

The bearings selected were for shafts one and fifteen-sixteenths inches in diameter, and as the shaft turns in direct contact with the rollers, the spindle used was a piece of regulation, cold-rolled, shop shafting of this size. This piece of shafting broke down before the bearings were affected. The ball bearings, of which three were used, were of the form shown in fig 1. In this figure the full form for a shaft is shown. In the test the bearing at one end was used. This consists of an inner ring of case-hardened steel fitted closely to the shaft and having a V groove cut around the outside. The balls travel between this groove and a corresponding outer groove. The sides of the outer groove are separate rings that are held in a frame, one fixed and the other adjustable by means of a screw thread cut on the inside of the frame, and a corresponding one cut on the outside of the ring. Adjustment of the bearing to the balls is gotten by means of this ring. This gives a four-point bearing in which the balls travel in planes perpendicular to the axis of the shaft. The balls were .5 inch in diameter.

The roller bearings used were of the form shown in fig. 2, in which, however, is shown a bearing having four sets. In the test, only one set

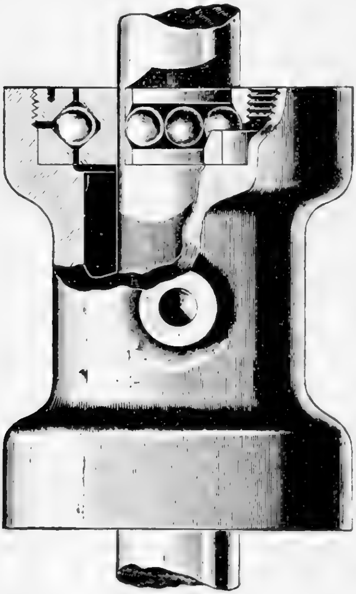


Fig. 1.

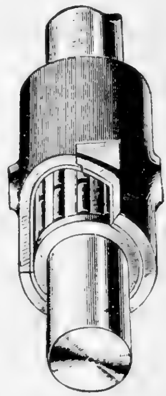
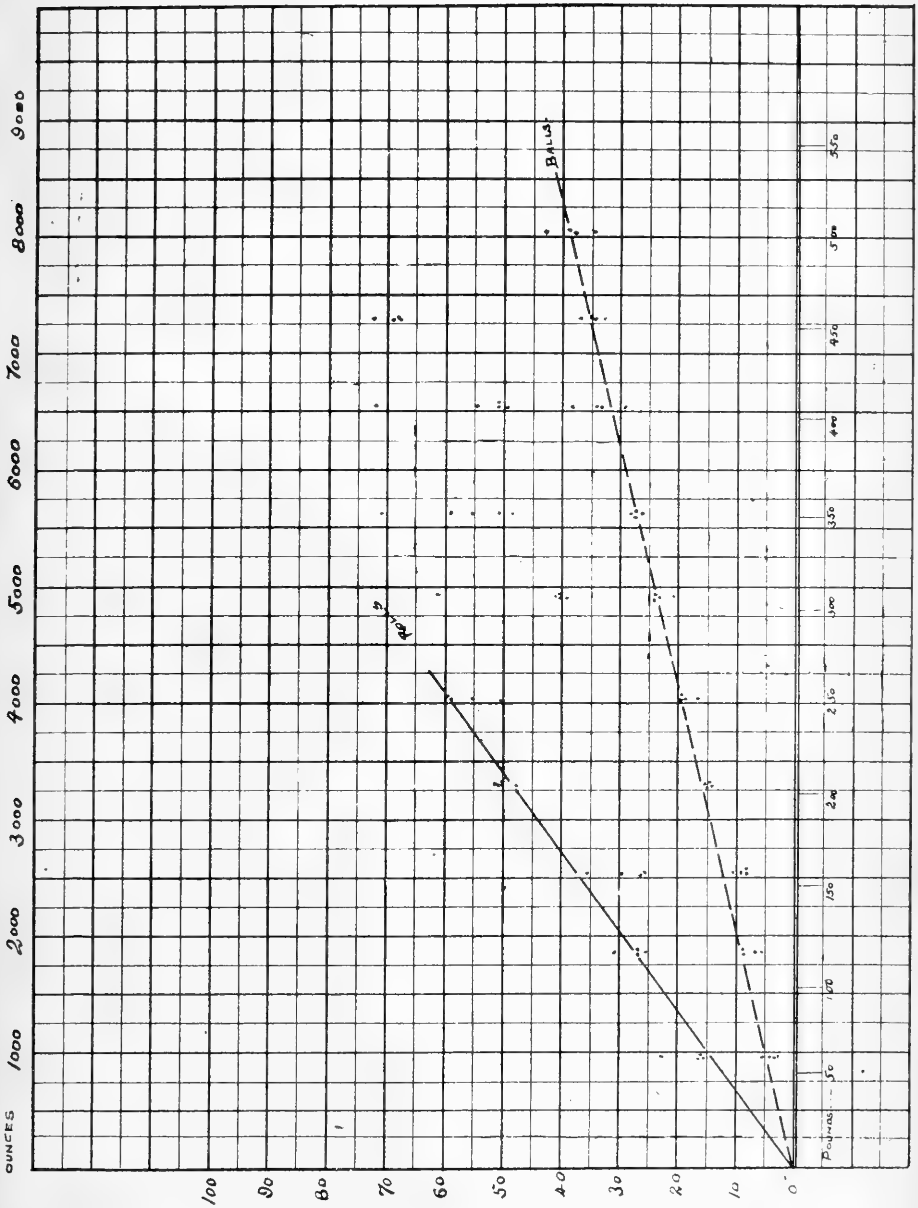


Fig. 2.

was used, as this was the unit in building the bearing. This consists of a cage holding fourteen small rolls, of hardened steel, each .315 inch in diameter and .625 inch long. These are separated from one another in the cage by brass bars. During the operation of the bearing the only friction between the cage and rolls ought to be that induced by the weight of the cage. It was found that the heavier loads caused the cage to become badly worn where there was contact between the ends of the rolls and the cage. The cage and rolls are held in a cylinder of steel that is carefully bored,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POUNDS
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500
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BALLS
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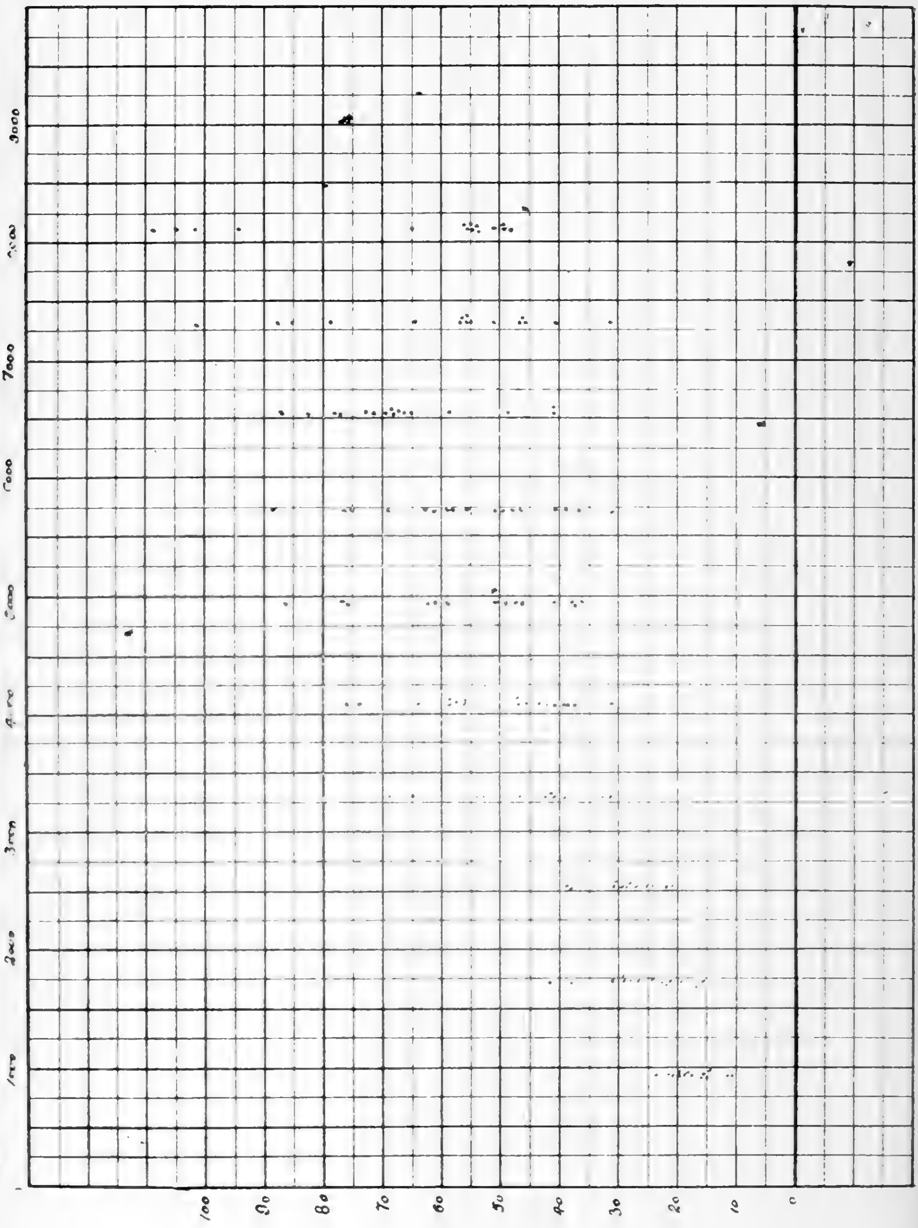
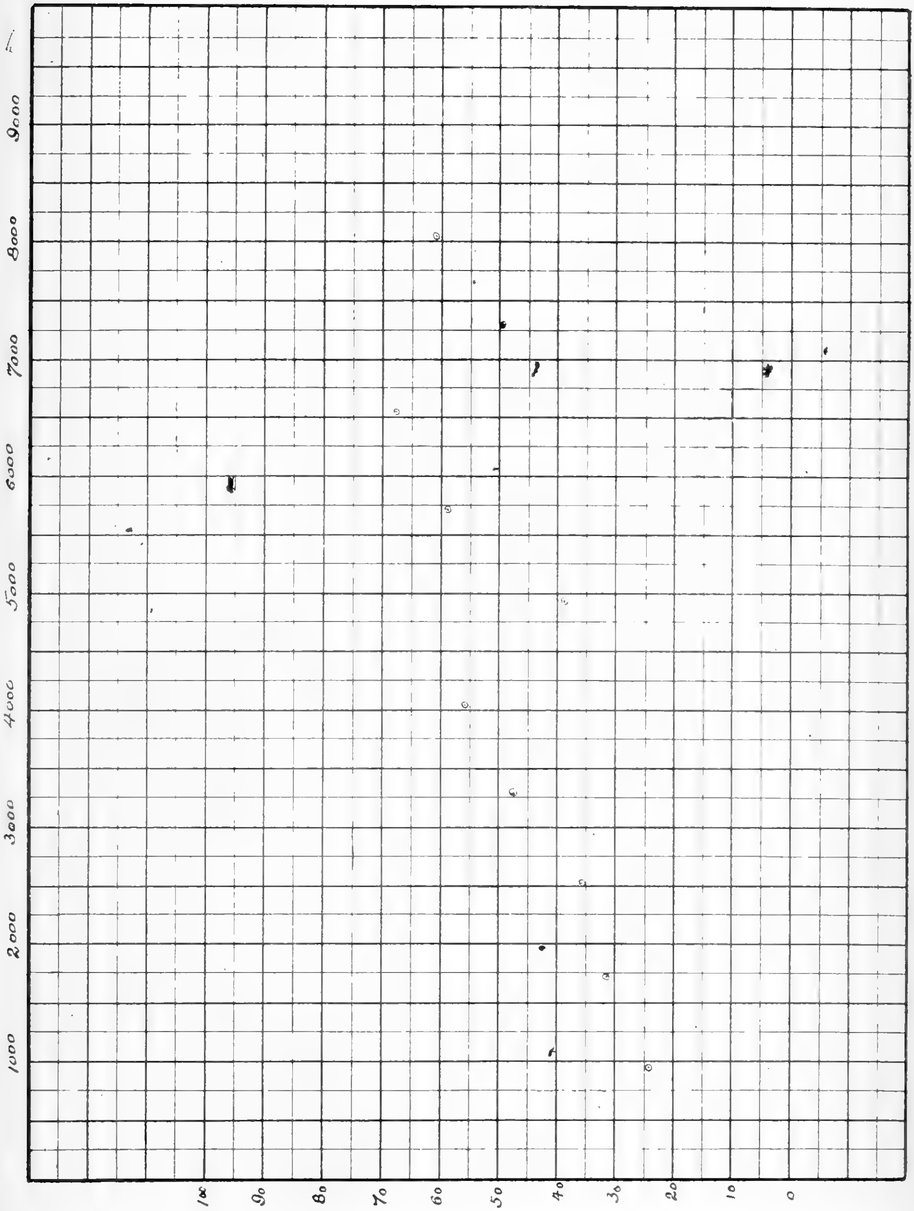
90
100

Sheet 2 Roller Bearing Test



Roller test... Speed = 1600 R.P.M.



Sheet 3.

then case-hardened and ground. No further grinding or other treatment to produce a greater degree of accuracy was given to any of the bearings used. Four tests were made at each of four speeds for every load, so that sixteen tests were made for each load. With some of the roller-bearing tests, where the results varied markedly, a greater number were made. In the curve of tests showing the comparative friction, each point is the average of four tests, so the position of the line is the result of sixteen tests. The loads were varied from fifty pounds to five hundred pounds. It was found that while the friction increased with the load in a nearly constant ratio for the balls, for the rolls there was a great variation at and after three hundred pounds. This is shown by the points on sheet 2. An examination of the shaft showed that it was being torn away in small flakes under the 300-pound load, and this tearing increased as the load was made greater. At 500 pounds the shaft was torn away quite rapidly, especially at the higher speeds, and after a few minutes' operation, a ridge was formed on the outside edges of the path of the rollers. This ridge had to be filed down on one side before the cage and rollers could be removed from the shaft. Neither the rolls nor their hardened steel race were affected, though, as already mentioned, the sides of the cage were cut by the ends of some of the rolls. Of the fourteen rolls in one cage, this wearing occurred at both ends of four of them. In making measurements on the dynamometer, a scale reading to fractions of ounces was used, so in plotting curves the unit used was the ounce.

The diagram of the friction curve for the roller bearings shows the points for the measurements taken at each load to be within spaces that increase slightly until the 250-pound load is passed, when the spaces between points increase in such manner as to show that the pull on the scale was due to more than the friction. It will be seen, however, that most of them seem to fall below the line made by the curve up to that point, if the line were produced. The points were so distributed that a curve drawn through the average position would not mean much. Why they fell so low in some cases I was unable to determine.

The diagram for the friction of the ball bearings shows the points within small spaces up to the 500-pounds load. How much farther this would continue with the kind of bearing used I did not determine, though I found on another test made on smaller balls and bearings, that both balls and bearings began to pit soon after the load exceeded 500 pounds, and that this pitting was very marked at 700 pounds. The small pieces torn from the balls and races were very different in shape from the flakes torn from the shaft by the rolls.

The diagram giving a comparison of the friction line of the two kinds of bearings shows the friction of the roller bearing to be more than twice as great as that of the ball bearing. Calculations from the figures taken during the tests gave the co-efficient of friction for the ball bearings used to be .00475, or less than one-half of one per cent., while that for the roller bearings was .014, or nearly one and one-half per cent. I have no doubt that if the shaft used was of steel, hardened and ground, as the rest of the parts were, that the friction would be reduced. As the shaft was torn by the rolls, new parts were brought into contact and a marked drop of the pull occurred.

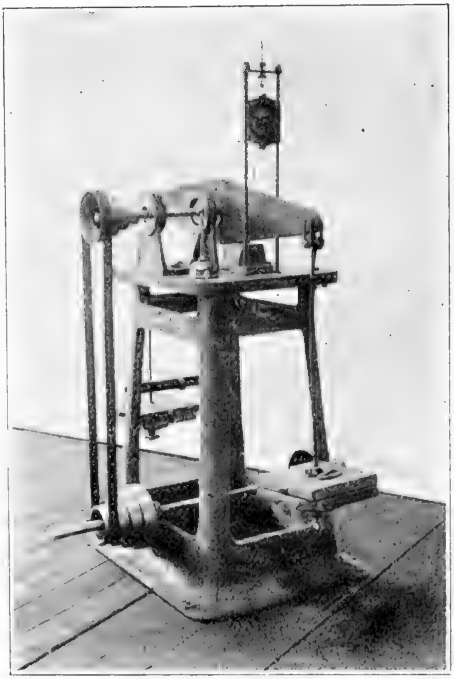
Bearing-Testing Dynamometer.

By M. J. Golden.

In making some tests to determine the amount of power lost by friction in different forms of shaft bearings, so much trouble was experienced in separating the loss in other parts of the apparatus used from that in the part being tested, when the regular transmission type of dynamometer was used, that the apparatus described here was devised for that purpose. It was tried in various forms experimentally before the present form was adopted. One of the rougher forms was described here last year in connection with a report then made on some bearing tests. In such tests the whole friction is so small that it is difficult to separate the friction due to the part being tested from that of the rest of the apparatus.

The machine as now used consists of a cast iron frame, made heavy enough to be stiff and to absorb a large portion of the vibration due to the rapidly moving parts. To the top of the frame is bolted a cast-iron table with planed surface. On this table are bolted two carriages, shown in the illustration at (a), that are fitted with ball bearings, in which a spindle or shaft revolves. These bearings are used because of the ease of alignment with them, and by fastening a set collar on each side of one of them end thrust is provided for. Different sizes of spindle may be used by having spare sleeves to be slipped on the smaller sizes and into the bearings.

The special features of the machine are the way in which the load is applied and measured. This is accomplished by having a stiff, cast-iron yoke (b), through the center of which the spindle passes. The ends of



the yoke project over the ends of the table and are provided with hardened steel knife edges (c) on which rods are hung, and the weights used for the load are suspended on these rods (d). The knife edges on which the weights are hung are on a line that passes an eighth of an inch above the center of the yoke, and as the rods are free to move on the edges, a nice balance of the yoke can be maintained. The bearing to be tested is placed in a cage that is fitted in the center of the yoke, and the shaft or spindle is revolved inside of it. The tendency of the yoke to revolve around the spindle, due to the friction of the bearing, is met in this way: At nine inches from the center of the yoke, and on the line of knife edges for weights, is an inverted knife edge (f). Above this a sensitive scale (e) is suspended and a link connection is made between the scale and the knife edge. The tendency of the yoke to revolve is met by the pull of the scale and the amount of the pull is registered on the scale.

Variation in speed is arranged for by placing on the end of the spindle that passes through the yoke a cone pulley of four steps (g), and this is driven by a belt from a corresponding cone pulley on a shaft (h) in the lower part of the frame. On this shaft is another cone pulley of three steps (j) driven from one on a countershaft. So a wide range of speeds can be gotten, and from a countershaft driven at 300 turns in a minute the spindle in the yoke has been made to revolve at speeds varying from thirty turns in a minute to 9,000 turns in a minute.

On the assumption that in some forms of bearings the suspension of the yoke on the spindle would be from some point near the top of the bearing, a yoke was made in which the knife edges for the weight rods could be raised and lowered, and some tests were made on different types of bearings with the edges at places above and below the center of the yoke; but though the suspension varied from the top to the bottom of the spindle no measureable change could be found.

To overcome the difficulty of finding the zero point for any test, a slightly greater weight was given to the scale side of the yoke than to the other side; and any one reading was made by driving the spindle first in one direction and then in the other, as this would give the amount of pull due to friction on the scale, as from the point found when driving one way to the corresponding point found when driving the other would be twice the amount that would be gotten when driving in either way alone.

The Toepler-Holtz Machine for Roentgen Rays.

By J. L. Campbell.

A Proposed Notation for the Geometry of the Triangle.

By Robt. J. Aley.

Everyone who has studied geometry very long has felt the need of a uniform notation. Much time is wasted in getting acquainted with the notations of different authors. This is especially true in modern pure geometry, where the figures are necessarily complex. The notation here proposed has been successfully used in the schoolroom. It is partially used by several well-known writers on modern geometry. It is hoped that its simplicity and system will commend it.

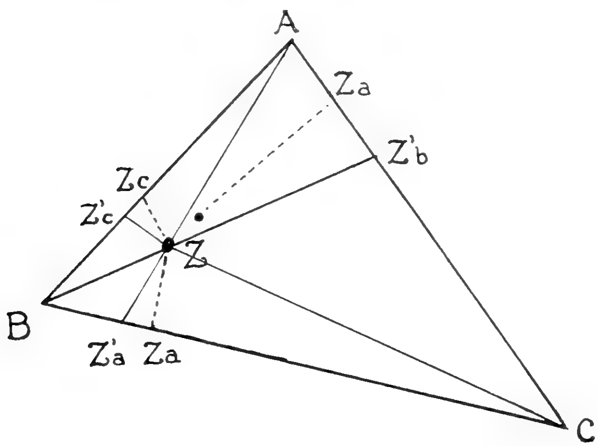
Let the triangle always be lettered ABC and in the usual positive direction of mathematics, i. e. counter clock-wise. Designate the sides, opposite the angles, a, b, c, and when necessary to refer to them by number, use 1, 2, 3. Particular points are made the basis of the notation. An example will make the method clear.

Suppose Z is some particular point. In studying such a point we usually need the points of intersection with the sides of the lines from the vertices through Z, and also the feet of the perpendiculars from Z to the sides. We designate the first set of points as Z'_a, Z'_b, Z'_c and the second as Z_a, Z_b, Z_c.

For the particular points, the symbol most frequently used has been in general selected.

A	B	C	=	vertices of the fundamental triangle.
	M		=	centre of the circumcircle.
M_a	M_b	M_c	=	mid-points of the sides of the triangle.
	I		=	centre of the inscribed circle.
I_1	I_2	I_3	=	centres of 1st, 2d, 3d escribed circles.
I_a	I_b	I_c	=	points of contact of sides with inscribed circle.
I'_a	I'_b	I'_c	=	points of intersection of AI, BI, CI with the sides.
I_{1a}	I_{1b}	I_{1c}	=	points of contact of sides with 1st escribed circle, and so on.
	G		=	centroid of ABC.
G_a	G_b	G_c	=	feet of perpendiculars to the sides from G.
	K		=	symmedian point (Grebe's).
K_a	K_b	K_c	=	feet of perpendiculars to the sides from K.
K'_a	K'_b	K'_c	=	points of intersection of AK, BK, CK with sides.
K_1	K_2	K_3	=	1st, 2d and 3d ex-symmedian points.
K_{1a}	K_{1b}	K_{1c}	=	feet of perpendiculars to the sides from K, and so on.
K'_{1a}	K'_{1b}	K'_{1c}	=	points of intersection of AK_1, BK_1, CK_1 with sides, and so on.
	H		=	ortho centre.

H_a	H_b	H_c	= feet of altitudes of triangle.
	Ω_1	Ω_2	= the Brocard points.
A_1	B_1	C_1	= Bocard's 1st triangle.
A_2	B_2	C_2	= Brocard's 2d triangle.
	F		= centre of the nine points circle.
	Q		= Nagel's point.
Q_1	Q_2	Q_3	= associated Nagel points.
A_3	B_3	C_3	= Nagel's triangle.
A_4	B_4	C_4	= Schwatt's triangle.
	N		= Tarry's point.
	R		= Steiner's point.
A′	B′	C′	= mid-points of the arcs of the circumcircle subtended by the sides of the triangle.
A″	B″	C″	= opposite points from A′B′C′ on circumcircle.
	P		= Gergonne point.
P_1	P_2	P_3	= the associated Gergonne points.
a	b	c	= the sides of the triangle.
h_1	h_2	h_3	= the three altitudes.
m_1	m_2	m_2	= the medians.
	r		= radius of incircle.
r_1	r_2	r_3	= radius of excircle.
	s		= $\frac{1}{2}(a + b + c)$.
s_1	s_2	s_3	= s — a, s — b, s — c.
	R		= radius of circumcircle.
$\triangle$	D		= area of triangle.



Some Circles Connected with the Triangle.

By Robt. J. Aley.

In my study of the geometry of the triangle I have frequently felt the need of an available collection of the circles connected with it. So far as I know, no such collection is extant. The following list, which is by no means complete, is offered as the beginning of what it is hoped may grow into an exhaustive collection.

1. *Circumcircle.*—The circle that passes through the vertices A, B, C of the triangle. Centre at M, the point of concurrence of perpendiculars erected at the mid-points of the sides. R, the radius $=\frac{abc}{\Delta}$.

2. *Incircle.*—The circle which is tangent internally to the three sides of the triangle. Centre at I, the point of concurrence of the three internal bisectors of the angles of the triangle. r, the radius $=\frac{\Delta}{S}$.

3. *Excircles.* The three circles which are tangent externally to one side and internally to two sides of the triangle. Centres are I_1, I_2, I_3, the points of concurrence of the external bisectors of the angles with the internal bisectors of A, B, C, respectively. The radii are $r_1=\frac{\Delta}{s-a}$, $r_2=\frac{\Delta}{s-b}$, and $r_3=\frac{\Delta}{s-c}$.

4. *Nine Points Circle.*—The circle which passes through the midpoints of the sides of the triangle, the feet of the perpendiculars, and the midpoints of the parts of the altitude between the orthocentre and the vertices. Centre is at F, the midpoint of IM. The radius is $\frac{1}{2}$ R. It is tangent to the incircle and to each of the excircles.

5. *Brocard Circle.*—The circle whose diameter is the line joining the circumcentre M, to the symmedian point K. It passes through the two Brocard points $\Omega_1 \Omega_2$ and through the vertices of Brocard's first and second triangles. Centre at midpoint of MK.

6. *Cosine Circle.*—The circle which passes through the six points of intersection of antiparallels through K with the sides. Centre is at K (Symmedian point).

7. *Ex-Cosine Circles.*—The three circles which have K_1, K_2, K_3 (ex-symmedian points) for centres, and which pass through B, C; C, A; and A, B, respectively.

8. *The Lemoine Circle.*—The circle which passes through the six intersections of parallels through K with the sides of the triangle. The centre is at the mid-

point of MK. The centre coincides with the centre of Brocard's Circle. The radius is equal to $\frac{1}{2}\sqrt{R^2+\rho^2}$ where ρ is the radius of the Cosine Circle. The segments cut out of the sides of the triangle by the circle are proportional to the cubes of the sides of the triangle. For this reason the circle is sometimes called the *Triplicate Ratio Circle.*

9. *Taylor's Circle.*—The circle which passes through the six projections of the vertices of the pedal triangle on the sides ot the fundamental triangle.

10. *Tucker's Circles.*—The circle that passes through six points determined as follows: If on the lines KA, KB, KC, points A′, B′, C′ are taken so that $KA' : KA = KB' : KB = KC' : KC =$ a constant, then the six points above referred to are the intersections of B′C′, C′A′ and A′B′ with the sides of ABC.

The centre is at the midpoint of the line joining M and the circumcentre of A′B′C′.

The circum-, Lemoine, Cosine and Taylor Circles are particular cases of Tucker Circles.

11. *Orthocentroidal Circle.*—The circle of similitude of the circum and nine-points circle. Centre at the midpoint of HG. Radius is $\frac{1}{2}$ HG.

12. *McCay's Circles.*—The three circles which circumscribe the triangles B_2C_2G, C_2A_2G, and A_2B_2G, respectively. ($A_2B_2C_2$ is Brocard's second triangle and G is the centroid.

13. *Polar Circle.*—This is the circle with respect to which the triangle is self-conjugate. Its centre is at H. It is real when H is outside the triangle, evanescent when H is at a vertex, and imaginary when H is within the triangle.

14. ——— *Circle.*—The circle on IM as diameter. It passes through A_5, B_5, C_5, which are the midpoints of AA′, BB′, CC′, respectively. (Proceedings Indiana Academy of Sciences, 1898, page 89.)

15. *Adam's Circle.*—The circle which passes through the six points determined by the intersection with the sides of the triangle of the lines through the Gergoume Point P, parallel to I_aI_b, I_aI_c, I_cI_a, respectively. The centre is at I.

16. ——— *Circles.*—Lines through P_1, P_2, P_3 (the associated Gergoume points), parallel to the sides of $I_{1a}I_{1b}I_c$, $I_{2a}I_{2b}I_{2c}$, and $I_{3a}I_{3b}I_{3c}$, respectively, determine sets of six points on the sides which are concyclic. The centres of these three circles are at I_1, I_2, and I_3. These circles might be called the associated Adam's circles.

The Point P and Some of Its Properties.

By Robert J. Aley.

P is the point of concurrence of the lines drawn from the vertices of a triangle to the points of contact of the inscribed circle with the sides. It has been called the Gergonne Point. The ratios of the distances of the point P from the sides are $\frac{1}{a(s-a)} : \frac{1}{b(s-b)} : \frac{1}{c(s-c)}$ (Aley, Contributions to Geom. of the Triangle, p. 10 (10)). From these ratios the actual distances of the point from the sides is easily found to be

$$PP_a = \frac{2\Delta(s-b)(s-c)}{a\Sigma(s-a)(s-b)}$$

$$PP_b = \frac{2\Delta(s-c)(s-a)}{b\Sigma(s-a)(s-b)}$$

$$PP_c = \frac{2\Delta(s-a)(s-b)}{c\Sigma(s-a)(s-b)}$$

P and Q (Nagel's Point) are isotomic conjugates and they are collinear with Z, the isotomic conjugate of I (incentre) (Ibid., page 8, III).

P_1 (the isogonal conjugate of P), Z_1 the isogonal conjugate of Z and K are collinear (Ibid., page 13, IV).

P_1, I and M are collinear.

The ratios of P_1 are $a(s-a) : b(s-b) : c(s-c)$ (Ibid., p. 3, 81).

From these the actual distances of P_1 from the sides is readily found to be

$$P_1P_{1a} = \frac{2\Delta a(s-a)}{S\Sigma a^2 - \Sigma a^3}$$

$$P_1P_{1b} = \frac{2\Delta b(s-b)}{S\Sigma a^2 - \Sigma a^3}$$

$$P_1P_{1c} = \frac{2\Delta c(s-c)}{S\Sigma a^2 - \Sigma a^3} \left\{ \text{Ibid., page 14, (7)} \right\}.$$

It is well known that

$$II_a = \frac{\Delta}{s}$$

$$II_b = \frac{\Delta}{s}$$

$$II_c = \frac{\Delta}{s}$$

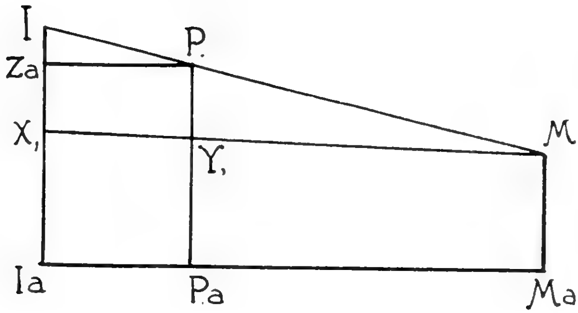
The ratios of M are $a(-a^2+b^2+c^2) : b(a^2-b^2+c^2) : c(a^2+b^2-c^2)$.

From these ratios it is easily found that

$$MM_a = \frac{a(-a^2 + b^2 + c^2)}{8\Delta}$$

$$MM_b = \frac{b\ a^2 - b^2 + c^2}{8\Delta}$$

$$MM_c = \frac{c(a^2 + b^2 - c^2)}{8\Delta}$$



$$IZ = II_a - P_I P_{Ia}$$

$$= \frac{\Delta}{S} - \frac{2\Delta a (S-a)}{S\Sigma_a{}^2 - \Sigma_a{}^3}$$

$$= \frac{\Delta}{S(S\Sigma_a{}^2 - \Sigma_a{}^3} \left\{ S\Sigma_a{}^2 - \Sigma_a{}^3 - 2aS(S-a) \right\}$$

$$= \frac{\Delta}{S(S\Sigma_a{}^2 - \Sigma_a{}^3)} \left\{ a^2b + a^2c + b^2c + bc^2 - 2abc - b^3 - c^3 \right\}$$

$$IX = II_a - MM_a$$

$$= \frac{\Delta}{S} - \frac{a(-a^2 - b^2 + c^2)}{8\Delta}$$

$$= \frac{1}{8S\Delta} \left\{ 8\Delta^2 - aS(-a^2 + b^2 + c^2) \right\}$$

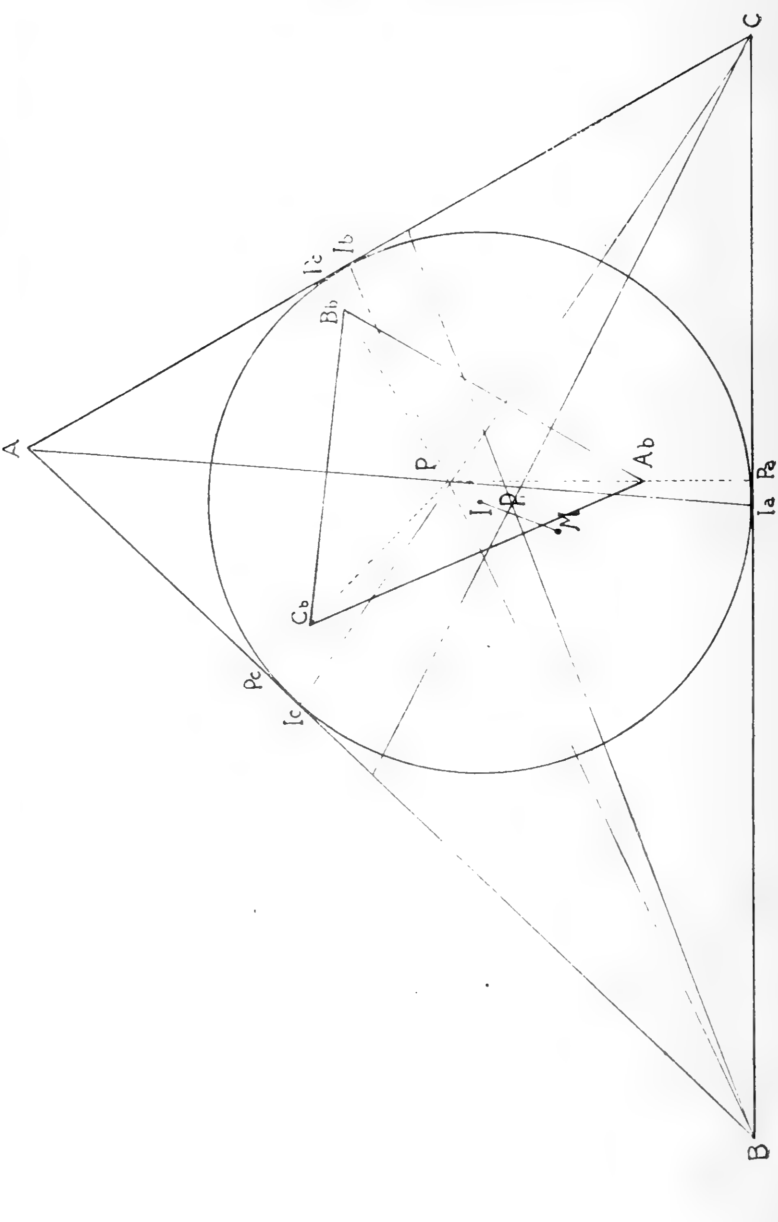
$$= \frac{8}{8S\Delta} \left\{ 8(S-a)(S-b)(S-c) - a(-a^2 + b^2 + c^2) \right\}$$

$$= \frac{S}{8S\Delta} \left\{ a^2b + a^2c + b^2c + bc^2 - 2abc - b^3 - c^3 \right\}$$

$$Iz : Ix = \frac{\Delta}{s(s\Sigma a^2 - \Sigma a^3)} (a^2b + a^2c + b^2c + bc^2 - 2abc - b^3 - c^3) :$$

$$: \frac{s}{8s\nabla} (a^2b + a^2c + b^2c + bc^2 - 2abc - b^3 - c^3) =$$

$$= 8\Delta^2 : s(s\Sigma a^2 - \Sigma a^3).$$


A
B
C
Bb
Cb
Ab
P
Ib
Pc
Ic
Ia
M

Similarly

$$IZ_2 : IX_2 = 8\Delta^2 : s(s\Sigma a^2 - \Sigma a^3)$$

And the same is true of $IZ_3 : IX_3$.

The points are therefore collinear.

$IZ_1 : IX_1 = IP_1 : IM$

$IP_1 : IM = 8\Delta^2 : S(S\Sigma a^2 - \Sigma a^3)$

$$IP_1 : P_1M = IP_1 : IM - IP_1 = 8\Delta^2 : s(s\Sigma a^2 - \Sigma a^3) - 8\Delta^2 =$$
$$= (-a+b+c)(a-b+c)(a+b-c) : s\Sigma a^2 - \Sigma a^3$$
$$-(-a+b+c)(a-b+c)(a+b-c).$$

The ratio of division is too complex for ordinary use.

If upon the lines PP_a, PP_b, PP_c equal distances from P be taken the triangle $A_6B_6C_6$ thus formed is similar to Nagel's triangle $A_3B_3C_3$.

For $\angle A_6PB_6 = \Pi - C$

And $\angle PA_6B_6 = \angle PB_6A_6 = \frac{1}{2}\,\xi(\Pi - \angle A_6PB_6) = \frac{1}{2}\,C$.

Similarly the $\angle PB_6C_6 = \frac{1}{2}\,A$.

And hence $\angle A_6B_6C_6 = \frac{1}{2}\,A + \frac{1}{2}\,C = \frac{1}{2}\,(A + C)$.

Likewise $\angle B_6C_6A_6 = \frac{1}{2}\,(A + B)$

And $\angle B_6A_6C_6 = \frac{1}{2}\,(B + C)$.

But these are the angles of Nagel's triangle and therefore $A_6B_6C_6$ is similar to $A_3B_3C_3$.

P is the symmedian point of the triangle $I_aI_bI_c$. (Proc. Edinburgh Math. Soc., Vol. XI., page 105).

If through P lines are drawn parallel to the I_aI_b, I_bI_c, I_cI_a respectively, the six points of intersection with the sides are concyclic. The circle is call Adam's circle.

DIAMOND FLUORESCENCE.

BY ARTHUR L. FOLEY.

[Abstract.]

Some three or four years since, I had occasion to cut a large number of photographic dry plates to smaller sizes. They were cut in the usual way with a diamond, and on the side of the plate opposite the film. In developing it was noticed that the film, to a breadth of a few millimeters along the edge of the plate, turned dark, as if exposed to light.

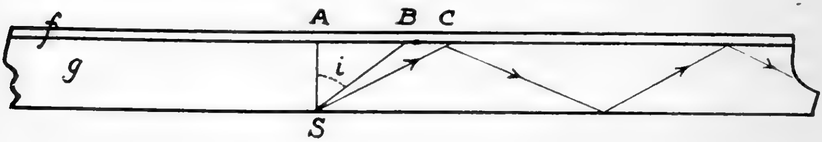
Several possible explanations suggested themselves:

1. The breaking of the glass might produce momentary fluorescence and a fogging of the film near the break.

2. The breaking or tearing of the film might result in some sort of change in its character.

3. The scratching of the diamond might set up mechanical disturbances or vibrations in the glass and these might affect the film.

4. The friction between the diamond and the glass might cause a momentary fluorescence along the line tracéd by the diamond, and the radiation might penetrate the glass and fog the film on the other side.



The last is the true explanation.

The first and second suggested explanations were thrown aside at once, for the dark line in the film was found to appear along the diamond-scratched line, whether the plate was broken or not. That the third explanation was not the true one was shown in several ways. The breadth and intensity of the dark lines did not appear to depend upon the depth of the cut or the rapidity with which it was made. The line was always of the same breadth on the same plate, but of different breadths on different plates. Moreover, the film always developed first on the side next the glass, which would not have been the case had the effect been due to any sort of strain or mechanical disturbance. The effect was noticeable on the most rapid plates only. Seed's "Gilt Edge" were used in most cases.

Let f represent the film on a section of the glass plate g, perpendicular to the diamond scratch s. Let us regard s as a source of radiation.

All rays (as s c) lying outside the critical angle i are totally reflected and hence do not affect the film. Those having an incident angle less than i penetrate the film and fog it if they are of sufficient intensity. The breadth of the fogged line is therefore—

$$b=2\ \overline{AB}=2\ t.\ \tan.\ i.$$

where t is the thickness of the glass plate and i is the critical angle for glass and the film substance.

Taking the indices of refraction of glass and gelatine for violet light, it was found that the equation is correct to within the degree of accuracy with which the various measurements could be made.

It was thought that the light produced by the friction of the diamond and glass might be sufficient to affect the eye. Nothing could be seen when the experiment was tried, although the observers had taken the precaution of staying in an absolutely dark room for an hour to render the eye as sensitive as possible. But this does not prove that no light resulted from the friction. A very feeble light would be sufficient to fog the plate when coming from a point so near the film. Besides, the fluorescence might have consisted of waves too short to affect the eye. In the formula I used the indices of refraction of violet light in order to obtain the value of the critical angle. For shorter waves the indices would be different, but their ratio probably would not be greatly different from the value used.

Later experiments have shown that fluorescence does not always occur when a diamond is drawn across a dry plate. I am not yet ready to say whether it is due to differences in different diamonds, to differences in the nature of the glass, or to changes in temperature, electrification, etc. I hope to be able to report more definitely at a future meeting.

Some Experiments on Locomotive Combustion.

By J. W. Shepherd.

Through the courtesy of the T. H. & I. Railroad officials, a study of the combustion in a locomotive while in operation was undertaken, the study being made from the analyses of the stack gases. The analyses were made with a modified Orsat apparatus.

The experiments were conducted on the large Schenectady passenger engines and on fast runs between Terre Haute and St. Louis, and Terre Haute and Indianapolis.

The apparatus for sampling the gases consisted of a half-inch gas pipe extending eight or ten inches into the center of the stack and bent uniformly following the outside of the stack to near its base, where another bend led it back to the cab on the fireman's side. Through this pipe, with the proper connections inside the cab, the gases were drawn into bottles by means of a steam jet. The bottles were fitted with ground-glass stoppers. The end of the gas pipe within the stack was fitted with a thimble, the lower end of which was solid steel and the sides perforated. This particular fitting was found to be essential to the successful operation of the apparatus.

Samples were taken in three different ways: (1) For periods of one to two minutes by displacement of water; (2) for continuous samples, from Terre Haute to terminals of road if desired, by displacement of water, and (3) for any period of time (brief as desired and whenever desired) by air displacement. In methods Nos. 1 and 2 the water displaced was acidulated with sulphuric acid. In method No. 3 the gas was passed five times before the bottle was disconnected from sampler.

Method No. 1 was not satisfactory, because the fireman did not fire normally during the sampling.

Method No. 2 showed that the value of a fire does not always vary directly as the increase of carbon dioxide and decrease of free oxygen in the stack gases. Samples Nos. 1 and 10 in the following table will serve as an illustration. No. 1 was taken continuously from Terre Haute to Effingham, Ill. (sixty-eight miles), and No. 10 from Effingham to East St. Louis (100 miles), both on same train, but different crews. No. 1 required less coal per car mile than No. 10. It is to be observed that No. 10 shows a percentage of carbon monoxide, which means that the rapid evolution of hydrocarbons resulted in a fuel loss, and is largely attributable to the kind of firing. No. 9 was also a continuous sample, between Terre Haute and Indianapolis, and showed the least coal consumption per car mile of any. This must mean that more volatile matter escaped in No. 1 than No. 9. Carbon monoxide was not determined in sample No. 1, but No. 9 was analyzed for it.

Samples Nos. 2, 3 and 4 furnish an interesting study on the evolution of the volatile-combustible matter.

Samples Nos. 5, 6, 7 and 8 show more strikingly the rate of volatilization. While the percentage of carbon dioxide in samples Nos. 5, 6 and 7 remains the same, it is to be noticed that the percentage of free oxygen decreases, which means increased volatilization.

As a rule samples show less uniformity than shop tests on account of the jarring motion of the locomotive.

It is intended to make other tests in conjunction with temperature determinations with a view of determining percentage losses.

No.	CO_2	CO	Free O	Kind of Firing.	Interval During Which Sample Was Taken From Time Fire Was Built.
1	9.1	......	8.8	Medium	Continuous.
2	14.0	0.8	2.6	Heavy.............	20–30 seconds.
3	13.7	0.5	2.6	Heavy.............	35–45 seconds.
4	12.6	0.0	5.4	Heavy.............	50–60 seconds.
5	10.0	......	8.9	One shovel.........	2–3 seconds.
6	10.0	......	8.4	One shovel.........	3–4 seconds.
7	10.0	......	5.5	One shovel.........	4–5 seconds.
8	9.4	......	8.7	One shovel.........	5–6 seconds.
9	7.9	0.0	10.4	Light..............	Continuous.
10	11.0	0.7	5.24	Heavy.............	Continuous.

Medium fire, 2–3 scoops.
Light fire, 1–2 scoops.
Heavy fire, 4–5 scoops.

Some Ionization Experiments.

By P. N. Evans.

The proportion existing between the ionized and un-ionized molecules of an electrolyte in (aqueous) solution, is represented by the equation $a \cdot b = k \cdot c$, in which a, b, and c are the concentrations of the anions, kathions and un-ionized molecules of the electrolyte, respectively, and k a constant depending on the nature of the electrolyte and independent of the concentration for moderately or highly dilute solutions.

Supposing this equilibrium to have become established, which is the case in an exceedingly brief time, if not instantaneously, any addition of either kind of ion concerned, the quantity of solvent remaining the same, must result in an increased value for its concentration and produce a corresponding increase in the number and concentration of the un-ionized molecules; for, k being a constant, any increase in the value of a or b will involve an increase of that of c if the equilibrium is to be maintained.

If to a saturated solution of an electrolyte there be added a second soluble electrolyte having an anion or kathion in common with the first, there must result a state of supersaturation with regard to the first electrolyte or a separation of a portion of it in insoluble form.

Many examples of this are familiar to all. For instance, a saturated solution of sodium chloride is instantly precipitated by the addition of concentrated hydrochloric acid, in spite of the water that is added at the same time; on the other hand, the case is complicated and the precipitation assisted, probably by the chemical union taking place between the hydrochloric acid and some of the water, made evident by the evolution of heat, thus increasing all the concentrations by removing (chemically changing) some of the solvent. The same result is obtained and the same reasoning applies when calcium chloride is added to a saturated sodium chloride solution. The precipitation of sodium chloride is brought about without this complication of causes by the addition of crystallized potassium chloride (KCl) or anhydrous sodium sulphate (Na_2SO_4), and even crystallized sodium sulphate ($Na_2SO_4.10H_2O$) gives the same result in spite of the water added in the crystals.

Similarly, potassium chloride can be precipitated by hydrochloric acid, sodium chloride (NaCl), or potassium sulphate (K_2SO_4); and copper sulphate ($CuSO_4.5H_2O$) by cupric chloride ($CuCl_2.2H_2O$), copper nitrate ($Cu(NO_3)_2$.

$6H_2O$), or sulphuric acid; barium chloride ($BaCl_2.2H_2O$) by hydrochloric acid, or sodium chloride; calcium sulphate ($CaSO_4.2H_2O$) by sulphuric acid, potassium sulphate, calcium nitrate ($Ca(NO_3)_2.4H_2O$); lead chloride ($PbCl_2$) by hydrochloric acid, sodium chloride, potassium chloride.

In this list we have a very wide range of solubility: 100 parts of water dissolve NaCl 35, KCl 32, $CuSO_4.5H_2O$ 40, $BaCl_2.2H_2O$ 33, $CaSO_4.2H_2O$ .20, $PbCl_2$ .74 parts. It is not evident whether easily or difficultly soluble substances should respond more readily in the yielding of a precipitate under these conditions, for the much greater degree of supersaturation attainable with an easily soluble substance may be offset by the greater difficulty in disturbing this state of supersaturation.

The greater the solubility of the electrolyte added to the saturated solution, the more readily a precipitate should be obtained; and the higher the dissociation constant of the second electrolyte, the more probable is a marked result.

In spite of the apparently favorable conditions in this respect, all attempts to precipitate lead chloride from its solution by means of lead nitrate were in vain. A saturated solution is very readily prepared by warming the solution in contact with an excess of the salt, and then cooling, owing to the great difference in solubility in hot and in cold water. The immediate and copious precipitate produced in this solution by the addition of sodium or potassium chloride or hydrochloric acid seemed to indicate that the tendency to remain in the supersaturated condition was very slight in the case of this salt, yet the addition of lead nitrate crystals to the solution (saturated), even in the considerable quantity made possible by the ready solubility of the nitrate (48 parts in 100), failed to cause any precipitation, either immediately or on long standing, or even on adding a crystal of lead chloride to induce crystallization from the solution, supposing it to be supersaturated. Lead nitrate, like most normal salts, has a high dissociation constant, more than half that of the strongest acids in a .1 per cent. solution (calculated by Arrhenius from conductivity experiments by Kohlrausch). This fact, and its high solubility, should be most favorable to the precipitation of the lead chloride, on account of the considerable increase in the concentration of the lead ions made possible thereby.

In harmony with the usual similarity of barium to lead, a saturated solution of barium chloride showed no sign of precipitation with barium nitrate ($Ba(NO_3)_2$); as already stated, a precipitate was produced by the addition of hydrochloric acid, or sodium or potassium chloride to the saturated barium chloride solution.

Similarly, potassium sulphate, though precipitated from its saturated solution by the addition of potassium chloride or sodium sulphate, gave no precipitate with sulphuric acid; and calcium sulphate was not thrown down by either sodium sulphate or ammonium sulphate but did separate slowly on the addition of potassium sulphate and more quickly with sulphuric acid.

Apparently, then, in these cases, the number of un-ionized molecules of the first is not increased by the addition of the second electrolyte, and the only plausible explanation seems to be that in these cases double salts are formed; e. g., lead-chloride-nitrate ($PbClNO_3$), barium-chloride-nitrate ($BaClNO_3$), hydrogen-potassium-sulphate ($HKSO_4$), calcium-sodium-sulphate ($CaNa_2(SO_4)_2$?), and calcium-ammonium-sulphate ($Ca(NH_4)_2(SO_4)_2$?).

Taking the case of lead chloride as an example, the addition of the lead nitrate must immediately increase the number of lead ions, but at the same time diminishes both this and the number of the chlorine ions by permitting the formation of lead-chloride-nitrate, so that the value of the product of the concentrations of lead and chlorine ions is not thereby increased, thus causing no rise in value of the concentration of the lead chloride, and, therefore, no separation of this substance as a precipitate. It does not follow that this peculiarity of behavior must accompany the formation of a double salt under similar circumstances, however, for it may be that the increase of the concentration of one kind of ion concerned may more than counterbalance the simultaneous decrease in this and that of the other kind of ion involved; this is simply a question of the value of the dissociation constants of the electrolytes present.

It seems probable that double salts exist in solutions whenever there is a polyvalent acid in presence of two or more bases or a polyvalent base in presence of two or more acids, though other evidence of the existence of most of these compounds is at present lacking. Since, however, we know and recognize the existence of only those double salts which separate out from solutions of their constituents rather than these constituents in distinct crystals, the evidence so far accepted for the existence of such compounds is of a very limited kind, namely, only their solubility relative to that of their constituents. In other words, if these separate in preference to the double compound, the latter does not exist so far as this kind of evidence is concerned.

Now, supposing that in a solution of equivalent quantities of the constituents the dissociation constants of these and the double salt are such that approximately equal numbers of molecules of the three kinds exist un-ionized, and the solution be concentrated, the double salt will separate if its molecular solubility (solubility divided by molecular weight) is less than that of either constituent, but not otherwise. Of course, it is not probable that the constants are such as to even approximately produce a condition like that imagined in the example just described, but inasmuch as normal salts do not differ very widely in their dissociation constants, the facts may be nearly enough in harmony with the supposition to make a study of these molecular solubilities not without interest in this connection, though the data available are not so numerous as might be desired.

An examination of the solubilities of twelve double salts selected at random showed the facts to be in accordance with this theory without a single exception. The figures are given in the following table, the formulas selected being those of the substances separating out as crystals from their solutions.

Formula.	*a. Molecular weight.*	*b. Solubility in 100 parts water.*	*b ÷ a × 100*
K_2SO_4	174	12.5	7.2
$Al_2(SO_4)_3.18H_2O$	665	85	12.8
$KAl(SO_4)_2.12H_2O$	474	9.5	2.0
$(NH_4)_2SO_4$	132	77	57.6
$Al_2(SO_4)_3.18H_2O$	665	85	12.8
$(NH_4)Al(SO_4)_2.12H_2O$	452	9	2.0
K_2SO_4	174	12.5	7.2
$Cr_2(SO_4)_3.18H_2O$	717	120	16.7
$KCr(SO_4)_2 12H_2O$	500	20	4.0
$(NH_4)_2SO_4$	132	77	57.6
$Cr_2(SO_4)_3.18H_2O$	717	120	16.7
$(NH_4)Cr(SO_4)_2.12H_2O$	478	over 12	over 2.5
K_2SO_4	174	12.5	7.2
$Fe_2(SO_4)_3.9H_2O$	562	over 80	over 14.1
$KFe(SO_4)_2.12H_2O$	503	20	4.0

Formula.	*a. Molecular weight.*	*b. Solubility in 100 parts water.*	$b \div a \times 100$
$(NH_4)_2SO_4$	132	77	57.6
$FeSO_4.7H_2O$	278	60	21.6
$(NH_4)_2Fe(SO_4)_2.6H_2O$	392	17	4.3
NH_4Cl	53.4	33	61.8
$SnCl_4.5H_2O$	350	over 1900	over 543
$(NH_4)_2SnCl_6$	366	33	9.0
K_2SO_4	174	12.5	7.2
$CaSO_4.2H_2O$	172	0.205	0.12
$CaK_2(SO_4)_2.H_2O$	328	0.25	0.08
K_2SO_4	174	12.5	7.2
$CoSO_4.7H_2O$	280	58	20.7
$K_2Co(SO_4)_2.6H_2O$	437	19	4.3
K_2SO_4	174	12.5	7.2
$NiSO_4.7H_2O$	281	67	23.9
$K_2Ni(SO_4)_2.6H_2O$	437	5.3	1.21
KCl	75	32	42.6
$MgCl_2.6H_2O$	203	130	64.0
$KMgCl_3.6H_2O$	278	64.5	23.2
K_2CO_3	138	110	80.0
$Na_2CO_3.10H_2O$	286	21	7.34
$KNaCO_3.6H_2O$	230	13	5.6

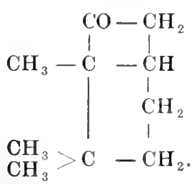
Synthesis of 2.3,3 – Trimethyl Cyclo-Pentanone, A Cyclic Derivative of Camphor.

By W. A. Noyes.

When a solution of the sodium derivative of methyl malonic ester and of the ethyl ester of γ-bromisocaproic acid in absolute alcohol is boiled on the water bath, about six per cent. of the brom-ester is converted into the ethyl ester of 2.3,3, tetramethyl-hexanoic 1, 2^1, 6-acid,

$$CH_3-C<\begin{matrix}CO_2C_2H_5\\CO_2C_2H_5\end{matrix} \quad | \quad \begin{matrix}CH_3\\CH_3\end{matrix}>C-CH_2CH_2CO_2C_2H_5.$$

The free acid, obtained by saponification of the ester with caustic potash, loses carbon dioxide when heated to 200° and is converted into α–$\beta\beta$–trimethyl-adipic acid, $CH_3-CH-CO_2H \;|\; \begin{matrix}CH_3\\CH_3\end{matrix}>C-CH_2-CH_2CO_2H$. When this acid is mixed with lime and distilled, 2.3,3–trimethyl cyclopentanone, $CH_3-CH-CO$, CH_2, $\begin{matrix}CH_3\\CH_3\end{matrix}>C-CH_2$, is formed. The oxime of this ketone was proved to be identical with the oxime of the ketone obtained by J. W. Shepherd and myself from α–hydroxydihydrocis-campholytic acid. This synthesis establishes, beyond reasonable doubt, the correctness of Bouveault's formula for camphor.



The details of the investigation appear in the American Chemical Journal, Vol. 23, p. 128.

Contributions to the Flora of Indiana. VI.

By Stanley Coulter.

In view of the publication in the near future of a catalogue of the phanerogamic flora of the State, this contribution is limited to a discussion of a few families, concerning which we have need of further knowledge. Each of these families, despite its familiarity, presents especial difficulties in the discrimination of species, difficulties which, as a rule, are not appreciated by the botanist who works remote from herbaria. Scant material and all too brief descriptions are responsible for a large proportion of the errors which have found their way into local lists.

POLYGONACEÆ.

Perhaps the greatest uncertainty exists in regard to the species of *Rumex* within the State. Of the eight species reported in the State, the following are undoubted: *R. Acetosella* L., *R. Britannica* L., *R. crispus* L., *R. obtusifolius* L., and *R. verticillatus* L.

Rumex altissimus Wood, reported from Jay, Delaware, Randolph and Wayne counties by Dr. Phinney, and from Dearborn County by Dr. Collins, is probably *R. Britannica* L., under mesophytic conditions. I have had several collections of the form referred to, *R. altissimus* Wood, for examination, and they take their place so naturally in a series of *R. Britannica* L., collected to show the effect of differing conditions upon the species, that it is impossible to avoid the suspicion that in many cases, at least, the forms referred to *altissimus* are really *Britannica*. I am unwilling to exclude the form from the State flora, not having seen the specimens of Dr. Phinney. I request, however, that if in any of the herbaria in the State there are forms referred to *altissimus*, they be examined with care and report made to me before the publication of the flora, instead of after its appearance.

R. occidentalis S. Wats. Reported from Jefferson County by J. M. Coulter, and from Clark County by Baird and Taylor, is probably to be excluded from the State list. There are no verifying specimens, and in fairly full collections of the genus made from those counties during two seasons the form does not appear. There is no especial reason why it should not be a member of our flora so far as its geographical distribution goes, and I should not be surprised if it were found in some of the herbaria of the State. If so a prompt report should be made.

Rumex sanguineus L., reported from Jefferson and Clark counties, shows itself, upon an examination of the specimens, to be *R. crispus* L., with the veins of the foliage leaves of a somewhat reddish cast. The outer characters are evidently those of *R. crispus* L. In the absence of further data *R. sanguineus* must be excluded from the State list.

It may be suggested at this point that few forms respond in so marked a manner to changed conditions as the docks. These changes involve the general habit, venation, inflorescence and markings of the valves. The collection of a single species under varying conditions will sufficiently explain the doubt felt in admitting to the State flora, without further evidence, the three forms just discussed.

The genus *Polygonum* is represented by nineteen species in our bounds. The specimens examined show a number of incorrect references, which serve to render doubtful some statements as to the distribution of these forms. Among the more common errors of reference are the following: *P. lapathifolium* L., for *P. incarnatum* Ell. The larger and more erect forms of *P. aviculare* L., for *P. erectum* L., while very often *P. Hydropiper* L., and *P. punctatum* Ell. =(*P. acre* H. B. K.) are found associated upon a single herbarium sheet. An examination of the ordinary descriptions of these species will show how easily such errors in reference may be made, and how small is the likelihood of their subsequent correction unless especial attention is called to them.

P. Careyi Olney is reported only from Noble County by Van Gorder. This is to my mind a very doubtful reference. The recorded range of the species is northern Maine and New Hampshire to Pennsylvania and Ontario, which militates somewhat against the accuracy of the reference, while the wide range of variation in the nearly related species *P. amphibium* L., and *P. emersum* (Michx.) Britton, (=*P. Muhlenbergii* Watson) suggest its proper reference is to one of these forms. My own experience in the collection of Polygonums in the same region leads me to believe the form to be *P. emersum*. *P. Careyi* Olney is, therefore, to be omitted from the State list unless other data are available.

P. ramosissimum Michx. is reported only from Vigo County, by W. S. Blatchley. The recognized range of the plant includes the whole State. It is probable that it is of fairly general distribution and has been mistaken for *P. erectum* L., from which it differs chiefly in its reduced and bract-like upper leaves.

P. tenue Michx., reported only from Tippecanoe County and Lake County, is in much the same case. It is probable that in most instances it has been mistaken for *P. aviculare* L., which it closely resembles in habit of growth and general aspect. Since recognizing it in Tippecanoe County I have been greatly surprised to find how abundantly it occurs. It would be well to examine herbarium specimens with some care for these two forms.

Generally speaking, the species of this genus can not be satisfactorily distinguished unless collected in fruit, a fact which seems to have been lost sight of in most of the herbarium sheets which have come to my notice.

GERANIACEÆ.

In this family, as at present limited, there are but the two genera *Geranium* and *Erodium*.

So far as I am able to determine the only species of geranium within our bounds are *G. Carolinianum* L. and *G. maculatum* L. Both seem of general distribution, although perhaps *maculatum* extends farther north and is everywhere much more abundant.

G. Robertianum L., reported from Dearborn County, by Dr. Collins, is probably *Carolinianum*. There is no apparent reason why *G. Robertianum* should not occur within the State, but as yet I have failed to find it in any collection. Several unpublished lists that have come into my hands have included *G. dissectum* L. The plants so referred are in every case depauperate forms of *G. Carolinianum* L.

Erodium cicutarium (L.) L'Her. is reported only from Gibson and Posey counties, by Dr. Schneck. It is to my mind very improbable that this rather rare, adventive plant, reported only from New York and Pennsylvania, should have found lodgement in these counties as a permanent member of our flora. Dr. Schneck preserved no specimens, but doubtful forms were passed upon by Dr. Gray. In my opinion the plant is not a member of the State flora, its admission in all probability being based upon a temporary escape. Unless additional data are at hand it will be dropped from the State list.

POLYGALACEÆ.

Eight species and one variety of the genus Polygala have been recorded in the State. Of these *Polygala Senega* L., *Polygala Senega latifolia* Torr. & Gray and *Polygala viridescens* L. (=*P.* sanguinia L.) are of general distribution and fairly abundant.

The following are reported from a single station:

P. ambigua Nutt. =(*P.* verticillata var. ambigua Wood), from Gibson and Posey counties, upon the authority of Dr. Schneck.

P. cruciata L., from Cass County, by Dr. Robert Hessler.

P. Nuttallii Torr. & Gray, from Jefferson County, by J. M. Coulter.

P. verticillata L. is reported from only two stations, Jefferson County and Noble County, while *P. polygama* Walt. is also reported but from two counties, Vigo and Elkhart. The difficulty of discriminating the species of this genus, because of their great variability and because of the fact that nearly related forms tend to become confluent, makes the inclusion of these forms reported from a single station a matter of some doubt. The material examined verifying the references has been so scant that critical study has been impossible. There is, however, in no instance any range improbability in the record. The well-known accuracy of the botanists reporting these forms is sufficient to justify their inclusion in the list. It is especially desirable that those in charge of herbaria should examine their Polygalas in the hope of both extending the range of these forms and justifying their inclusion in the State list.

VIOLACEÆ.

Sixteen species of the genus Viola have been recorded from the State, at least four of which seem questionable, so much so, indeed, that without additional evidence they should be excluded from the State list.

Viola hastata Michx., reported only from Clark County, upon the authority of Baird and Taylor, is a mountain form. It occurs in the Alleghanies in Pennsylvania and follows the system southward. It has an additional station in the extreme northeastern part of Ohio, but apart from this is confined to the mountain regions. It is closely allied to *V. pubescens*, Ait.,, from which it differs essentially in the size of the stipules. The halberd-shaped leaf often passing into an oblong to heart-shaped, while the broadly heart-shaped leaves of *pubescens* as frequently narrow.

The reference is undoubtedly incorrect, the plant being a narrow-leaved, rather glabrous form of the *V. pubescens* Ait.

V. primulaefolia L., reported as rare in moist soil in Gibson and Posey counties, by Dr. Schneck, I am forced to regard as a form of *V. blanda* Willd. *V. primulaefolia* is an eastern plant, ranging from New England to Florida near the coast. A glance at the descriptions of *blanda* and *primulaefolia* will serve to show how, with slight foliar changes, it might be possible to mistake the two forms. I have examined for intervening stations so far as I was able, but have found none that indicate even the slightest western movement of the species.

V. rostrata Pursh, reported from Jefferson County ("Clifty Ravine"), by C. R. Barnes, and from Noble County, by VanGorder is a rather rare northern form, extending southward along the Alleghanies. Of the two stations, that in Noble County would be the more probable. I have seen no specimen verifying either citation, but because of the known range of the form am inclined to refer it to a form of *V. striata* Ait. The most constant difference between *rostrata* and *striata* is in the spur. In the former it is slender and longer than the petals; in the latter it is thickish and shorter than the petals. It may, however, be a form of *V. Labradorica* Schrank (=V. canina var. Muhlenbergii Gray). I feel confident, however, that *V. rostrata* Pursh is not a member of the State flora.

Viola rotundifolia Michx., reported from Dearborn County, by Dr. Collins, and from Jefferson County, by Professor Young, is another eastern mountain form, whose presence in our territory is scarcely possible and certainly is very improbable. The recorded range of the plant reads: "Cold woods; Maine to Minnesota and southward along the Alleghanies." The form is so characteristic that it is difficult to understand with what species it may have been confused. The range probabilities, however, are so strongly against its presence in the State that in the absence of verifying specimens it must be excluded from the catalogue.

The admitted forms of the genus are as follows:

V. blanda Willd.

V. Canadensis L.

V. Labradorica Schrank (=V. canina var. Muhlenbergii Gray) a form not recorded north of Monroe County.

V. lanceolata L.

V. obliqua Hill (=V. palmata var. cucullata Gray).

V. palmata L.

V. pedata L.

V. pedatifida Don., reported from Wayne County, and also from Gibson and Posey. The form is western and is probably confined to the western tier of counties. The Wayne County reference is probably *V. pedata*.

V. pubescens Ait.

V. sagittata Ait., apparently confined to southern counties.

V. striata Ait.

V. tricolor L.

PLANTAGINACEÆ.

An examination of a large number of specimens from various localities referred to *Plantago major* L., showed the majority of them to be *P. Rugelii* Dec. The only character that readily separates the two forms is the number of seeds in the pod. In the case of *major*, running from eight to eighteen, and in *Rugelii* from four to nine. As the pods are of practically the same size, the difference in the size of the seeds is easily recognized. It is probable that in almost every region of the State *P. Rugelii* Dec. will be found in fair abundance closely associated with *P. major* L. The two forms run into each other in leaf, spike and bract characters, but may apparently always be separated by the number and size of seeds.

COMPOSITÆ.

Vernonia gigantea (Walt.) Brit., =(V. altissima Nutt.) is of much more general distribution than indicated in my Contribution to Flora of Indiana, IV, page 5. In the northwestern counties of the State it seems more abundant than *V. fasciculata* Michx., to which it is usually referred. In almost every collection thus far examined, *gigantea* is the prevailing form. I am inclined to believe it much more abundant in the State than *V. fasciculata* Michx.

As suggested in Contribution IV (supra), there are many reasons which lead to the belief that *gigantea* is really a hybrid and should be written *V. Noveborascensis* × *fasciculata*. Experiments are now under way for the determination of this point.

Through the courtesy of Dr. Eigenmann, I have received a list of plants of the northern lake regions of the State, which fairly represents the flora of such restricted areas in the months of August and September. The list is herewith published in the form in which it was received, with thanks to Mr. Deam for the use of his notes. Comments upon some of the species are reserved for the forthcoming report upon the flora of the State.

A LIST OF PLANTS COLLECTED AT CEDAR, SHRINER AND ROUND LAKES.

By C. C. Deam, Bluffton.

The following species are represented in my herbarium by specimens collected by Mr. Williamson and myself. The number here recorded by no means represents the rich flora of the region.

Dryopteris Thelypteris (L.). A. Gray. September 2, 1897. Shriner Lake.

Typha latifolia L. September 2, 1897. Round Lake.

Potamogeton, four species. August 3, 1896. Shriner Lake.

Sagittaria rigida Pursh. August 6, 1896. Round Lake.

Panicum capillare L. August 6, 1896. Round Lake.

Panicum Crus-galli L. August 2, 1896. Round Lake.

Zizania aquatica L. August 6, 1896. Round Lake.

Homalocenchrus oryzoides (L.). Poll. September 2, 1897. Cedar Lake.

Muhlenbergia Mexicana (L.). Trin. September 2, 1897. Shriner Lake.

Cyperus Engelmanni Steud. September 1, 1897. Shriner Lake.

Cyperus rivularis Kunth. September 1, 1897. Round Lake.

Dulichium arundinaceum (L.). Britt. September 1, 1897. Round Lake.

Eleocharis interstincta (Vahl.). R. and S. September 1, 1897. Round Lake.

Eleocharis mutata (L.). R. and S. September 2, 1897. Round Lake.

Scirpus Americanus Pers. August 3, 1896. Shriner Lake.

Scirpus atrovirens Muhl. August 2, 1896. Shriner Lake.

Scirpus lacustris L. August 1, 1896. Shriner Lake.

Scirpus lineatus Michx. August 1, 1896. Shriner Lake.

Rynchospora glomerata (L.). Vahl. August 2, 1896. Round Lake.

Cladium mariscoides (Muhl.). Torr. September 2, 1897. Shriner Lake.

Carex comosa Boott. September 1, 1897. Shriner Lake.

Carex lupuliformis Sartwell. September 1, 1897. Shriner Lake.

Eriocaulon septangulare With. September 2, 1897. Round Lake.

Pontederia cordata L. August 1, 1896. Shriner Lake.

Juncus Canadensis J. Gay. September 2, 1897. Shriner Lake.

Pogonia trianthophora (Sw.). B. S. P. August 2, 1896. Shriner Lake.

Corallorhiza odontorhiza (Willd). Nutt. August 8, 1896. Round Lake.
Rumex verticillatus L. September 2, 1897. Cedar Lake.
Polygonum incarnatum Ell. August 6, 1896. Round Lake.
Polygonum punctatum Ell. September 2, 1897. Round Lake.
Polygonum sagittatum L. September 2, 1897. Cedar Lake.
Amaranthus blitoides S. Wats. September 2, 1897. Round Lake.
Silene stellata (L.) Ait. August 6, 1896. Round Lake.
Brasenia purpurea (Michx.). Casp. August 3, 1896. Shriner Lake.
Nymphæa advena Soland. August 6, 1896. Round Lake.
Castalia odorata (Dryand). Woodv. and Wood. August 3, 1896. Round Lake.
Actæa alba (L). Mill. August 3, 1896. Round Lake.
Hamamelis Virginiana L. August 1, 1896. Cedar Lake.
Spiræa salicifolia L. August 4, 1896. Cedar Lake.
Cassia Marylandica L. August 1, 1896. Round Lake.
Meibomia Dillenii (Darl.) Kuntze. September 1, 1897. Round Lake.
Meibomia Michauxii Vail. September 1, 1897. Round Lake.
Meibonia nudiflora (L.). Kuntze. July 30, 1896. Round Lake.
Lespedeza frutescens (L.). Britton. September 1, 1897. Round Lake.
Lespedeza Virginica (L.). Britton. September 1, 1897. Round Lake.
Euphorbia corollata L. September 3, 1897. Cedar Lake.
Celastrus scandens L. August 1, 1896. Round Lake.
Impatiens aurea Muhl. July 29, 1896. Shriner Lake.
Decodon verticillatus (L.). Ell. August 6, 1896. Round Lake.
Myriophyllum, one species. August 3, 1896. Round Lake.
Cicuta bulbifera L. September 2, 1897. Round Lake.
Cicuta maculata L. August 3, 1896. Round Lake.
Scutellaria galericulata L. August 2, 1896. Round Lake.
Scutellaria laterifolia L. September 3, 1897. Round Lake.
Monarda fistulosa L. August 4, 1896. Round Lake.
Lycopus rubellus Moench. September 1, 1897. Shriner Lake.
Mentha piperita L. July 31, 1896. Round Lake.
Gerardia paupercula (A. Gray). Britton. September 1, 1897. Shriner Lake.
Utricularia resupinata B. D. Greene. September 2, 1897. Round Lake.
Utricularia vulgare L. June 24, 1898. Shriner Lake.
Cephalanthus occidentalis L. August 3, 1896. Shriner Lake.
Lobelia cardinalis L. July 31, 1896. Round Lake.
Lactuca villosa Jacq. September 2, 1897. Cedar Lake.
Hieracium scabrum Michx. September 1, 1897. Round Lake.

Eupatorium purpureum L. July 31, 1896. Round Lake.

Solidago, one species. August 6, 1896. Cedar Lake.

Euthamia graminifolia (L.). Nutt. August 1, 1896. Cedar Lake.

Aster macrophyllus L. August 6, 1896. Round Lake.

Inula Helenium L. August 6, 1896. Round Lake.

Silphium trifoliatum L. July 31, 1896. Round Lake.

Rudbeckia laciniata L. September 2, 1897. Cedar Lake.

Bidens Beckii Torr. August 6, 1896. Round Lake.

Bidens trichosperma (Michx.). Britt. August 6, 1896. Round Lake.

Erechtites hieracifolia (L.). Raf. September 2, 1897. Cedar Lake.

Carduus muticus (Michx.). Pers. September 2, 1897. Cedar Lake.

Some Unrecognized Forms of Native Trees.

By Stanley Coulter.

In the case of certain of our familiar forests there is a popular or commercial recognition of certain well-marked forms which have either escaped the attention of botanists or have been considered of such slight importance as to receive no mention in descriptive works. Some of these forms are so distinct and so persistent as to raise the question as to whether they may not be entitled to varietal rank. Certainly in a study of our forest flora they must be taken into account. I desire in this paper to call atention to some of these botanically unrecognized forms, hoping by this means to receive added information upon this point.

ASIMINA TRILOBA DUNAL.

The papaw has two easily distinguishable forms, which may be characterized as—

1. A large-fruited form, becoming a rich yellow upon ripening.
2. A small-fruited form, remaining white upon ripening.

Among the evident fruit differences the following are to be noted. In the large-fruited form the pulp is much softer and more yielding than in the small-fruited form; it possesses a much stronger flavor and odor; the seeds are less numerous, although somewhat larger. The color of the outer skin changes to black under the action of frost, while in the small-fruited type it remains green. Form 1 furnishes the really edible fruit. The larger form is also in cross section, almost circular, while the small-fruited form is elliptical, being compressed dorso-ventrally.

In habit, form 1 is the taller plant, the branches are more appressed, and the bark is a decided brown. In form 2, the branches are spreading and the bark much lighter in color, being gray rather than brown.

The inner bark of form 1, after maceration in water, is used in making rough ropes and withes; that of number 2 can not be so used, being much more brittle, or rather of much less tensile strength.

As compared with form 2, the leaves of form 1 are larger, more acute, a deeper green and much more highly odorous. The leaves of the papaw are popularly supposed to possess preservative properties and are used to cover meat, dressed poultry and fish, butter, etc. For this purpose only the leaves of form 1 are used. Large areas of the other forms will be passed over in the search for the highly odorous leaves of the large-fruited form. In histological features, the leaves of the two forms differ chiefly in the palisade layer and the relative thickness of the outer walls of the epidermis. This later, in form 2, being from two to four times thicker than in its larger leaved relative.

The date of flowering differs slightly, form 2 opening its smaller, less deeply colored flowers from a week to ten days later than form 1.

In our area form 2 has much the wider soil range. While always associated with form 1, it also thrives in a much thinner, lighter soil and in drier situations. When growing together, the two forms are easily separable, never by any chance becoming confluent.

While not of the opinion that these differences are sufficient to create a new species, I am inclined to think that in our area form 2 should have recognition as a distinct form, and suggest that it be known as *alba*.

JUGLANS NIGRA L.—Black Walnut.

Of this familiar tree there exists in Indiana two if not three easily separable forms:

1. Fruit spherical, nut following shape of hull; hull thick, bright green in immature state, turning black upon ripening; pulp becoming

black and very soft under the action of frost; kernel very oily, of somewhat rank flavor.

2. Fruit ovoid, much smaller than in number 1. Nut following shape of hull; hull relatively thin, bright green in immature state, turning yellow upon ripening or under the influence of frost; pulp drying up and hardening at maturation; kernel dry (not markedly oily), and of an agreeable flavor. This is the form which the wood-wise boy gathers for his winter supply.

The leaf of form 2 is much smaller than that of form 1, the leaflets being smaller, more sharply acute and finely serrate; they are also much less vividly green than those of form 1, a difference in color that seems due to the thicker epidermis.

Form number 2 grows in drier situations than form 1, though occasionally extending into the regions of the latter. In these cases there seems to be no blending of forms. The two forms are sharply distinct wherever associated.

Lumbermen assert that the wood of form 2 is much lighter in color and of much less commercial value than that of form 1. Whether or not there is difference in the period of flowering and maturation of fruit I am unable to state. Form 1 is that of ordinary descriptive botanists, form 2 not being noted or indicated. In our area it is of general occurrence and is known by the boys as the "little black walnut."

Form 3, so far as I know, is found only in a few localities near Lafayette. The fruit closely resembles the English walnut in some particulars, while in others it resembles the butternut. The hull is thin and without appreciable pulp at any season. The shell is very thin, the nut cracking as easily as the English walnut. The kernel is not at all oily and is very sweet. Some few trees are found upon the west bank of the Wabash River near Lafayette, and a few others near the Purdue campus. This form I described before the Academy of Science in 1890 under the title of "*An Aberrant Form of Juglans nigra.*" In that paper I suggested the fruit peculiarity was due to an early defoliation of the trees which occurred that year. Observations continued from that time until the present convince me that the opinion there expressed is not borne out by facts. The form has maintained itself in the stations indicated through these years from 1890 to 1900, its fruit always presenting the features given above. Dr. Schneck suggests that it is a hybrid of *J. cinerea* × *J. regia* in which he follows J. Robinson in "Our Trees" (published by the Essex

Institute), in which a similar form is recorded. I am inclined to doubt the fact of the hybrid nature of the form for reasons that need not be considered in this connection. Whatever the origin of the form, it is definitely established in the two stations indicated. I hope during the coming season, in the case of both the papaw and walnuts, to discover whether or not these variations show a tendency to a "place mode."

LIRIODENDRON TULIPIFERA L.—Tulip Tree. Yellow Poplar. White Poplar.

Lumbermen distinguish between "yellow poplar" and "white poplar," a difference based upon the color of the wood. So far as I am able to judge, this difference is dependent upon the age of the tree and the soil conditions, being associated with no structural differences. In my opinion, it will be found that trees of this species, growing in tenacious clay soils, have the denser structure and darker color characterizing the yellow poplar, while in light, dry soils and loam, the white poplar is found. In both conditions the wood of the older trees is of a darker color, in some cases approaching brown. I hope that a series of observations now in progress will make it possible to determine the relation between the soil character and these alleged commercial varieties. If there is any method by which the two forms are to be distinguished by flower, fruit, leaf or bark characters, it has escaped my attention.

DIOSPYROS VIRGINIANA L.—Persimmon.

This tree shows at least two, perhaps three, sharply distinct forms existing in the same area without becoming confluent. A discussion of these differences is unnecessary since in "*The American Persimmon*," Bulletin No. 60, Vol. VII, of the Agricultural Experiment Station of Purdue University, Messrs. Troop and Hadley discuss these variations fully. I quote a few sentences from this bulletin:

"They differ in quality as much as our cultivated apples. Some are very astringent, others are insipid and worthless, still others are sweet and delicious.

"The fruit differs in size from that of a small wild plum to an inch and one-half or two inches in diameter. They also vary greatly in form;

some are globular, others either conical or oblong, those of the globular form predominating."

The wide soil range of the persimmon indicates that these differences may be dependent upon soil character, at least in large measure. A warm soil well exposed to the sun is best adapted to the persimmon, but it is found on almost any kind of soil from rich bottom land to the thin soil of hill tops. In Lawrence and Orange counties, according to Messrs. Troop and Hadley, it is found in great luxuriance in red clay soil areas, in lands exhausted by persistent cropping and which had been abandoned as worthless.

In this wide range of soil conditions it would seem possible to determine with some accuracy the effect of soil character upon this species.

I have called attention to these variations chiefly as an intimation that our forest flora is much less perfectly known than its importance merits, and in the hope that it will direct attention to the range of variation in these and other species.

Seedlings of Certain Native Herbaceous Plants.

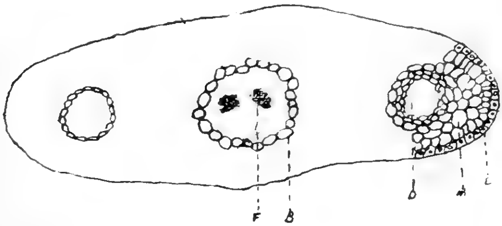
By Stanley Coulter and Herman B. Dorner.

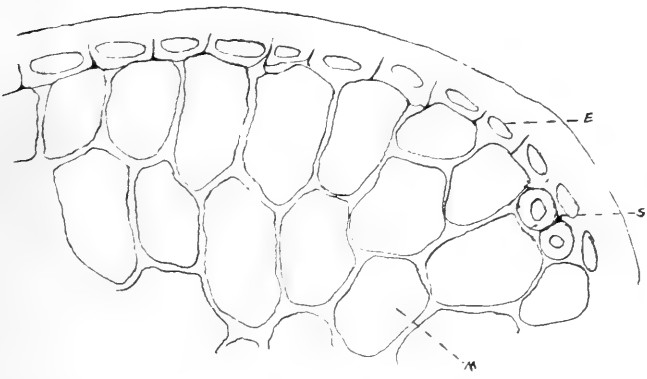
The Resin Ducts and Strengthening Cells of Abies and Picea.

By Herman B. Dorner.

Of recent years great strides have been made in systematic botany, especially in the line of adding new determinative features to classification. At the present time not only external features, but also internal structures are used for the determination of generæ and species. This system of classification, according to internal structure, has best been carried out in the genus Pinus.

The first work done upon the pines with the internal structure in view, was done by F. Thomas in 1865. Further study was made upon the subject by C. E. Bertrand in 1871-74 and W. B. McNab in 1875-77. However, the first man to study the subject closely was the late Dr. George Engelmann, whose name is more intimately associated with the conifers than that of any other man. His first work along this line was his "Synopsis of American Firs," which was published in 1878 in the Trans. St. Louis





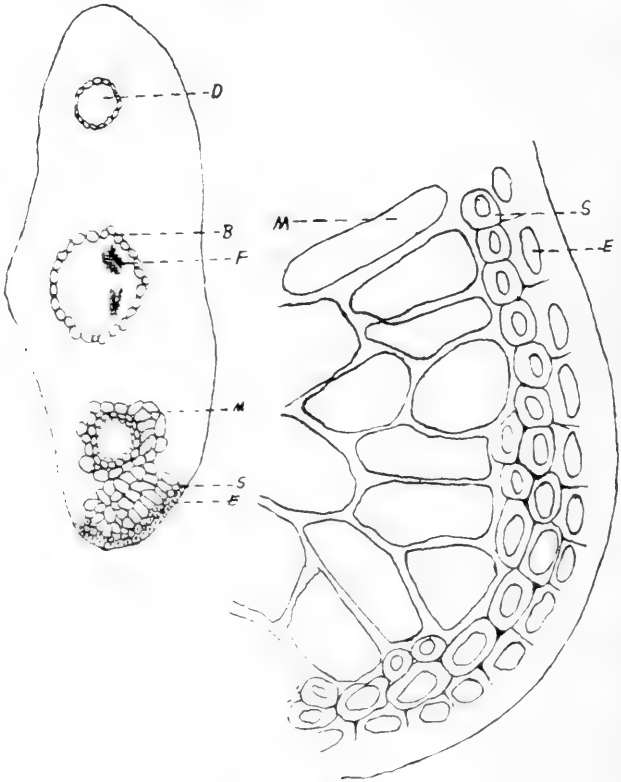
ABIES BALSAMEA.

D Ducts.
B Bundle sheath.
F Fibro-vas. bundle.
M Mesophyll.
E Epidermis.
S Strength. cells.

Acad. III, pp. 593-602. In 1880 there appeared in the same journal, IV, pp. 161-189, his "Revision of the Genus Pinus." However, in the second paper he merely used the internal structure to distinguish between the different subdivisions of the genus.

It is at this point that J. M. Coulter and J. N. Rose took up the work. Their idea was to apply the characters obtained not only to the subdivisions but to the species as well. The results of this work appeared in 1886 in the "Botanical Gazette," XI, pp. 256-262 and 302-309.

The object of their study was to determine whether the pines could be separated from one another by means of the structure of the foliage

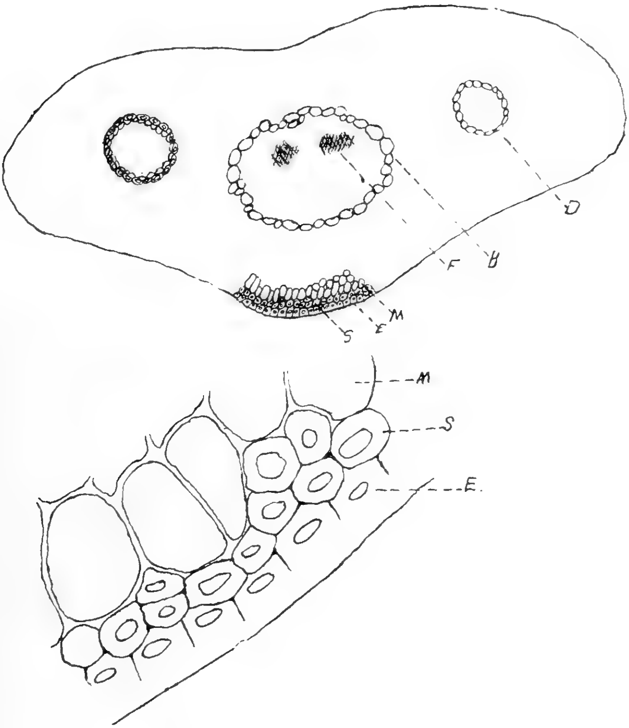


ABIES FRASERI.

D Ducts.
B Bundle sheath.
F Fibro-vas. bundle.
M Mesophyll.
S Strength. cells.
E Epidermis.

leaf. The material used by them was gathered from as large a range as possible and thus have the material grown under as many conditions as possible. Their determinative features were based upon the number of fibro-vascular bundles, the position and kind of strengthening cells, the position of the stomata, the number and position of the ducts, thickness of the walls of the bundle sheath, and the number of leaves in a fasicle. With these characters, which appeared to be permanent ones, a system of classification was formulated which was very useful in connection with the classification based upon external features.

Since this time comparatively little, if any, work has been done upon



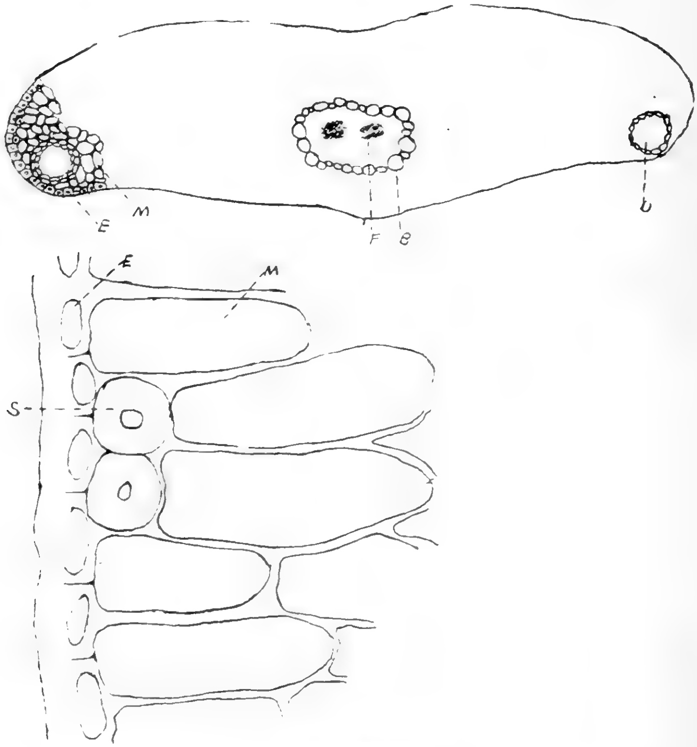
ABIES SUBALPINA.

D Ducts.
B Bundle sheath.
F Fibro-vas. bundle.
M Mesophyll.
E Epidermis.
S Strength. cells.

the Coniferae in this line. It was with this same end in view that the study of the generæ Abies and Picea was taken up. The object here, as in the case of the Pinus, was to work out the characteristic features of the species of the two generæ and find their determinative value.

The material used was obtained of C. S. Sargent of the Arnold Arboretum, and comprised only truly American species. The collection consisted of six species of Abies and five of Picea, all of the United States.

In preparing the leaves for study, transverse sections were made through the center of the leaf so as to avoid the danger of getting sections without the characteristic number of ducts or fibro-vascular bundles. Al-



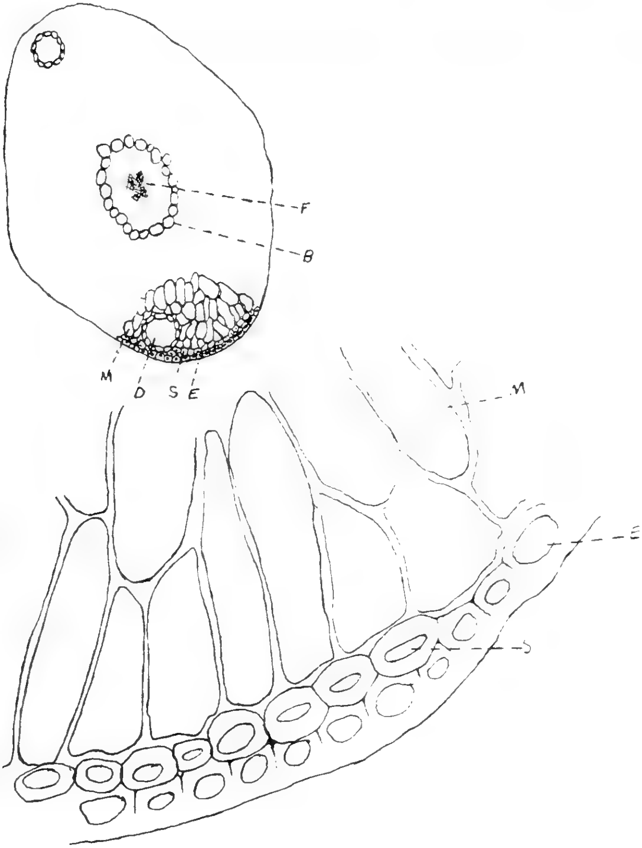
ABIES GRANDIS.

D Ducts.
B Bundle sheath.
F Fibro-vas. bundle.
M Mesophyll.
E Epidermis.
S Strength. cells.

together, between five and six hundred specimens were studied. In this determination only features represented in these transverse sections were used.

In the genus Abies the leaf structure is essentially the same as that of the genus Pinus. The leaf, as a whole, is divided into three parts, the *cortical*, or outer part, the *mesophyll*, or chlorophyll-bearing part, and the *fibro-vascular* region surrounded by its bundle sheath.

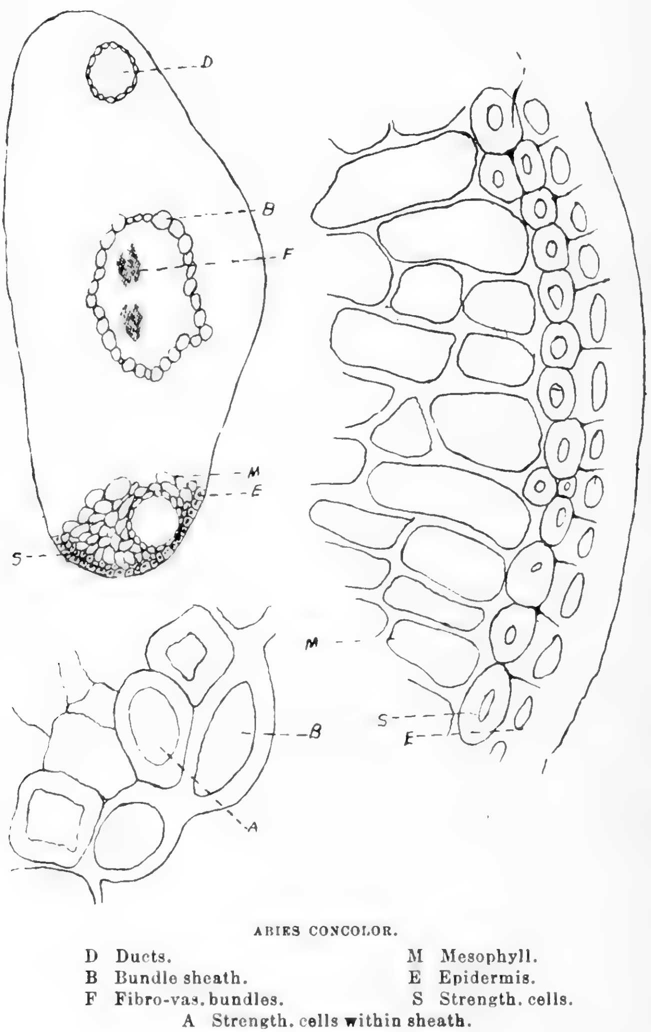
The *cortical* region is composed of an epidermis and a series of strengthening cells lying directly beneath. The epidermis is composed of



ABIES MAGNIFICA.

D Ducts.
F Fibro-vas. bundle.
B Bundle sheath.
M Mesophyll.
E Epidermis.
S Strength. cells.

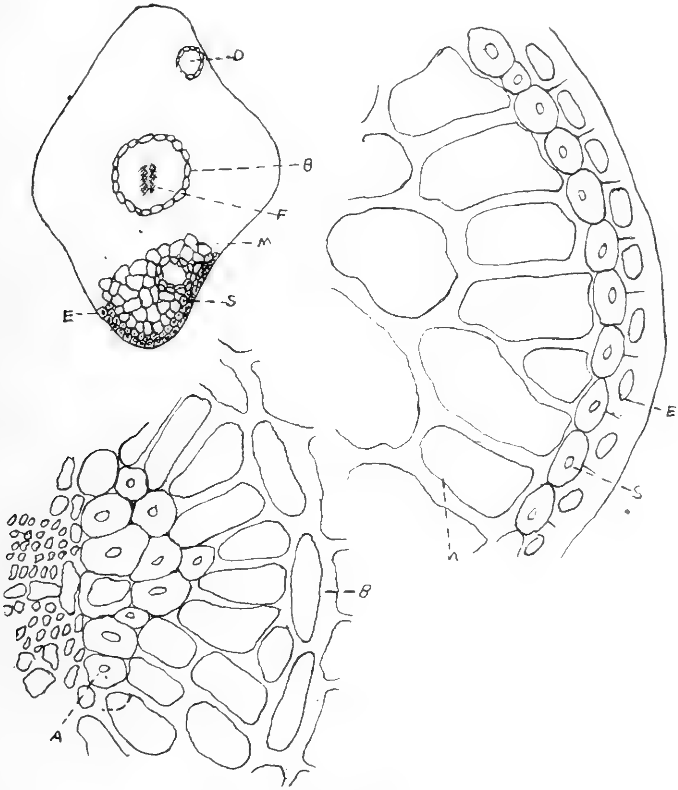
a single layer of thick-walled cells with a cuticle twice as thick as the lumen of the cell. This epidermis is broken by the openings of the stomata. These stomata are arranged in rows down the sides of the leaf in the hollows between the angles. The strengthening cells are all thick walled and without content. For convenience these cells will be referred to as thin and thick walled but the terms are mere relative ones. The term strengthening cell, as here used, refers to these thick-walled cells wherever found.



ABIES CONCOLOR.

D Ducts. M Mesophyll.
B Bundle sheath. E Epidermis.
F Fibro-vas. bundles. S Strength. cells.
A Strength. cells within sheath.

The *mesophyll* region is composed of chlorophyll-bearing, parenchyma cells. These cells differ from the corresponding ones of the pine, in that they do not show that characteristic infolding of the cell wall. The cell walls are smooth, more like the parenchyma of an ordinary leaf. It is within this region that the resin ducts occur. These ducts may be either *peripheral* when they lie directly under the epidermis, or *medial* when they lie entirely surrounded by the parenchyma. These lie parallel to the longer axis of the leaf and are surrounded by a series of strengthening cells. Lining the inside of the duct is a single layer of secretory cells.

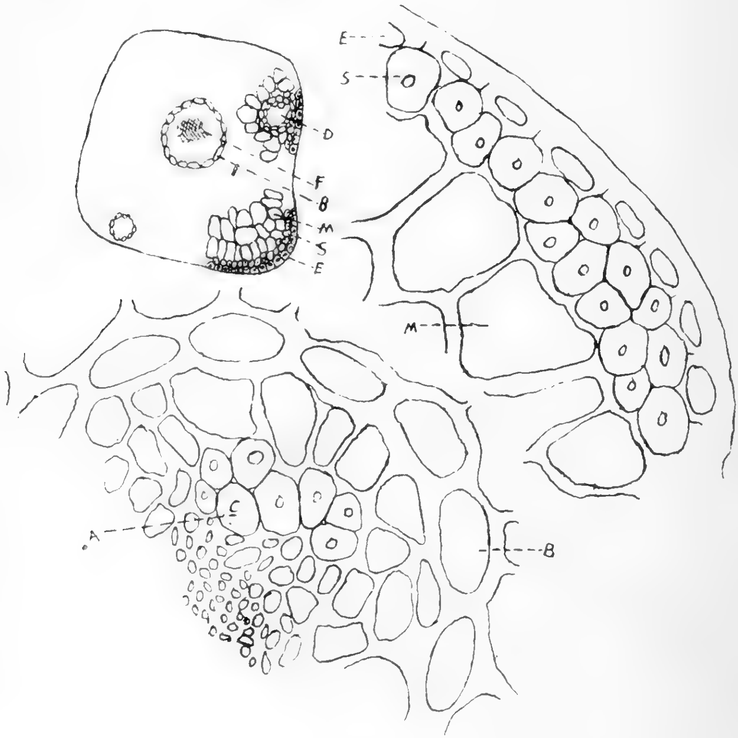


PICEA MARIANA.

D Ducts.	M Mesophyll.
B Bundle sheath.	S Strength. cells.
F Fibro-vas. bundles.	E Epidermis.

A Strength. cells within sheath.

The *fibro-vascular* region lies in the center of the leaf and is surrounded by a somewhat imperfect bundle sheath. The sheath is composed of large and small cells intermingled. In the center lie the fibro-vascular bundles, which are two in number, with the exception of Abies magnifica, where the two seem to have merged into one. Strengthening cells sometimes appear within the bundle sheath and seem to be a constant feature in the species in which they occur.



PICEA RUBRA.

D Ducts.	E Epidermis.
S Strength. cells.	M Mesophyll.
F Fibro-vas. bundle.	B Bundle sheath.

A Strength. cells within sheath.

From the characteristics above mentioned the following synoptical arrangement of the genus has been arranged.

*Ducts medial.

†Strengthening cells absent or few in number.

1. *Abies balsamea* (L.) Mill. Strengthening cells few in number or entirely absent, thin walled.

††Strengthening cells always present in considerable numbers.

2. *Abies Fraseri* (Pursh.) Lindl. Strengthening cells in a continuous layer within the epidermis, sometimes doubling at the angles, especially the dorsal angles. Cells thin walled..

3. *Abies subalpina*, Engelmann. Strengthening cells mostly in the angles; in a single layer in the lateral angles and a double or triple row in dorsal angle, also occurring in groups between the angles.

**Ducts peripheral.

†Strengthening cells few in number, occurring singly or in groups.

4. *Abies grandis*, Lindley. Strengthening cells occurring singly or in groups of from two to five, thick walled. sometimes occur within bundle sheath.

††Strengthening cells abundant in angles of the leaf in single or double rows.

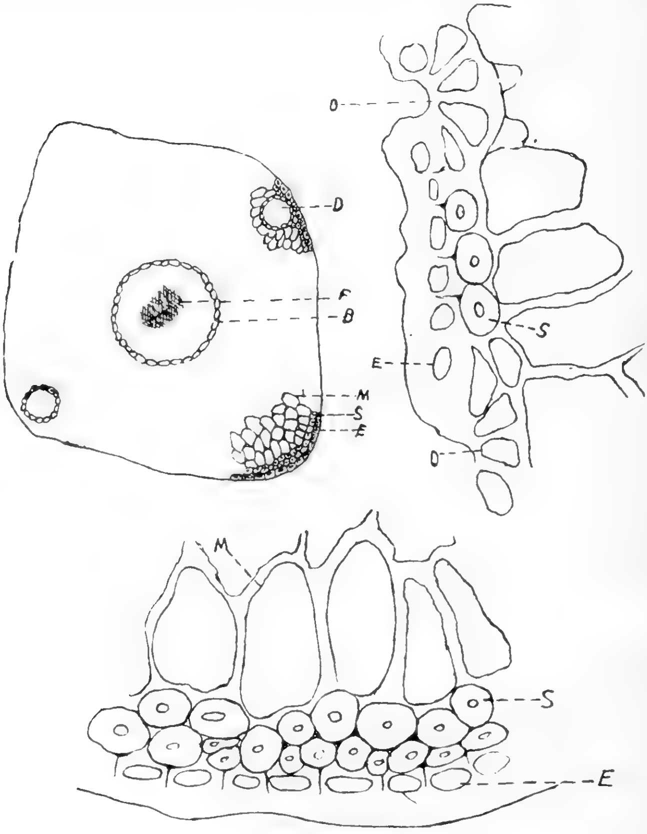
5. *Abies magnifica*, Murray. Strengthening cells thick walled. The two vascular bundles merged into one.

6. *Abies concolor*, Lindley and Gordon. Strengthening cells very thick walled, some present within the bundle sheath.

The structure of the leaf of the Picea is about the same as that of the Abies. The leaf, however, is of a different shape. In the cross section the Abies show a lateral axis very much longer than the dorsi-ventral axis. In the Picea the two axes are about equal. There are also other characteristic differences. The leaf, as in the Abies, is divided into *cortical*, *mesophyll* and *fibro-vascular* regions.

The *cortical* region. The epidermis is composed of thick-walled cells as in the Abies. The strengthening cells are arranged about the entire leaf, and like the epidermis, this layer is interrupted only by the stomata. The stomata here are also arranged in rows along the side of the leaf. Between the openings of the stomata the strengthening cells are much thinner walled than in the remainder of the leaf.

The *mesophyll* region is composed of wavy-margined, chlorophyll-bearing, parenchyma cells. This region also contains the ducts, which vary from none to two in number. It appears as if the number of ducts should be two, if the leaf be bi-laterally symmetrical. However, in Picea Canadensis never more than one duct was found in a single leaf. Dissatisfied

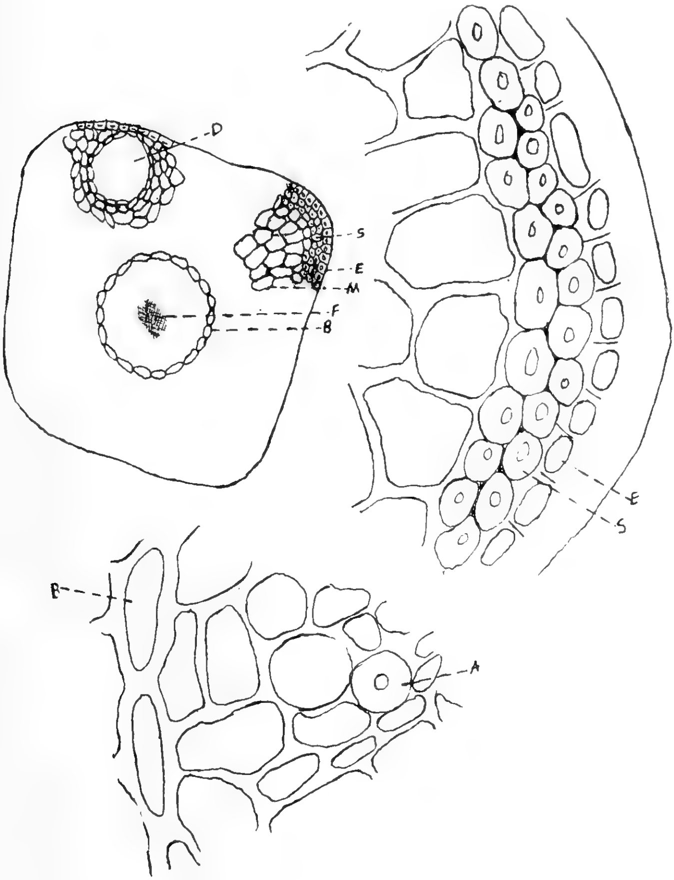


PICEA PUNGENS.

D Ducts. E Epidermis.
S Strength. cells. M Mesophyll.
F Fibro-vas. bundle. B Bundle sheath.
O Stomata.

with this variation of the number of ducts, sections were made through the entire leaf. From these sections it was found that the duct did not extend the entire length of the leaf, but was somewhat spindle-shaped, with the widest part in the center of the leaf and then gradually tapering to either end. This accounts, then, for the variation of the number of ducts. The ducts are all peripheral and are surrounded by a single layer of strengthening cells and lined by a layer of secretory cells.

The *fibro-vascular* region lies in the center of the leaf and is surrounded



PICEA ENGELMANNI.

D Ducts. E Epidermis.
S Strength. cells. M Mesophyll.
F Fibro-vas. bundle. B Bundle sheath.
A Strength cell within sheath.

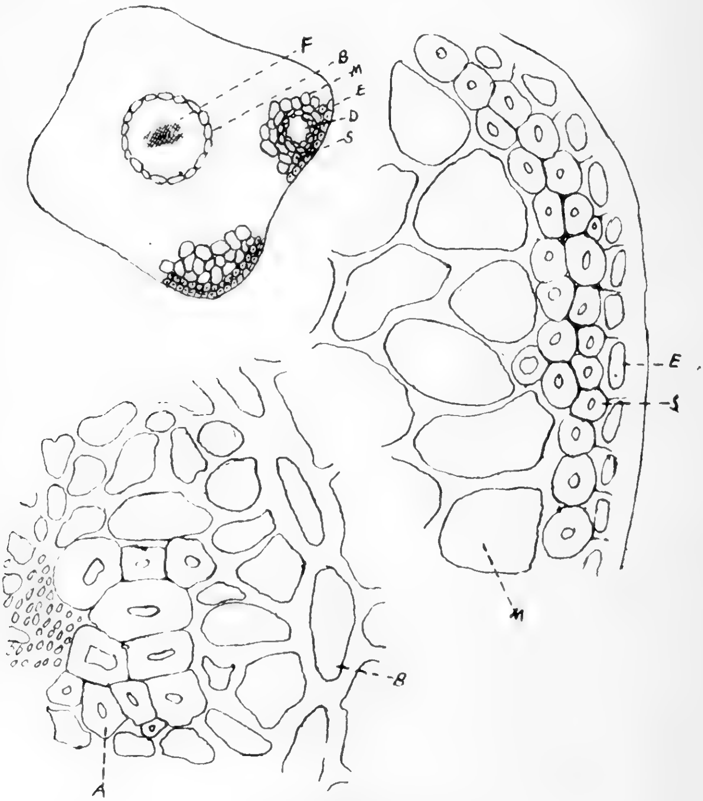
by a very regular bundle sheath. In all five species only one *fibro-vascular* bundle is present. Strengthening cells may or may not be present in this region, but when present are good determinative features.

From the data secured from the study of the Picea, the following arrangement has been made:

*Ducts always *two*.

†Lateral axis much longer than dorsi-ventral axis.

1. *Picea Mariana* (Mill.) B. S. P. Strengthening cells in a single row, very thick walled, some occur within bundle sheath.



PICEA CANADENSIS (Alba).

D Ducts. M Mesophyll.
S Strength. cells. E Epidermis.
F Fibro-vas. bundle. B Bundle sheath.
A Strength. cells within sheath.

†Lateral axis and dorsi-ventral axis about equal.

2. *Picea rubra* (Lamb.) Link. Strengthening cells very thick walled, occurring in a single row, sometimes doubled or tripled at the angles. Some strengthening cells occur within the sheath.

**Ducts *none* to *two*.

3. *Picea pungens* Engelmann. Strengthening cells thick walled, some thick-walled cells occurring singly or in groups between the stomata, with tendency to double row at the angles.

4. *Picea Engelmanni* Engelmann. Strengthening cells in a single row, sometimes doubled at the angles; thick walled. A single cell sometimes occurs within the bundle sheath.

***Ducts *none* to *one*.

5. *Picea Canadensis* (Will.) B. S. P. (=Picea alba Link.). Strengthening cells in a single row sometimes doubled at the angles; very thick walled; some occur within bundle sheath.

Although the above synoptical arrangements appear to be conclusive within themselves they are valuable only in conjunction with the external features.

A Proteolytic Enzyme of Yeast.

By Katherine E. Golden.

INTRODUCTION.

The enzymes are auxiliary substances which are formed where solid bodies are to be liquefied. They are peculiar in that they decompose complex substances without being affected themselves in any way by the action, and also that even in minute quantities they can produce very marked results. They are important in animal and plant metabolism and occur both in the cells and in solution in secretions of the cells. In the case of unicellular organisms, the metabolic processes are carried on throughout their entire substance, the food substance being absorbed into the cell, where the enzyme is formed and does its work. This, however, is not always the case, the enzyme sometimes being excreted, the work of absorption following its action. This latter process is peculiar to multicellular organisms, having certain parts differentiated for special work, the enzymes being formed in one set of cells, and excreted into the parts where the absorption of food takes place.

The composition of the enzymes is not known, some inclining to the view that they are of a proteid nature, while others think that they are nucleo-proteid, but as yet it is not definitely settled, as the enzymes have not been obtained in a pure condition, their reactions being connected with those of the substances with which they are associated. On account of this lack of knowledge as to their composition the enzymes have been classified according to the substances which they decompose.

The proteolytic enzymes are those which decompose proteids into less complex substances. There are two classes of these, the peptic and tryptic enzymes. The peptic enzymes decompose proteids to peptones, while the tryptic enzymes go farther, effecting the decomposition of the peptones to amides. In plants the amides are formed as antecedents to proteids, helping in the reconstruction of proteids as well as aiding in their osmosis by decomposition. When the carbohydrate, which was united with the amide, forming the proteid, is used up, the amide unites with a fresh carbohydrate, again forming a proteid. The enzyme in the plant, which causes this decomposition, is often in such minute quantity that it is almost impossible to determine its presence.*

Only a very few of the vegetable proteolytic enzymes have been investigated, and nearly all of these are from the higher plants. Those which have been investigated minutely have been found to be of a tryptic nature. A few of the fungi have also been found to secrete a proteolytic enzyme among these yeast.[1] It is claimed that if yeast be deprived of both oxygen and food material that it breaks up its own reserve proteid, and also, that if yeast be pressed, and the extract collected and heated to 45° C., a bulky coagulum is formed, which disappears in a few days, the extract in the meantime being kept under antiseptic conditions. The digestion of the reserve proteid and the disappearance of the coagulum indicate the presence of a proteolytic enzyme.

Proteolysis by yeasts has been noted but indirectly, except in the case of the pressing from the yeast of an extract by Büchner.[2] Jörgensen,[3] in describing S. Jörgensenii and S. membranæfaciens states that the

* Kerner and Oliver. Natural History of Plants. Vol. I, part 2.

[1] Green, J. R. The Soluble Ferments and Fermentation, 1899, pp. 215-217.

[2] Büchner, E. Ber. d. deut. chem. Gesell., 1897.

[3] Jörgensen, A. Micro organisms and Fermentation, 1893.

yeasts cause a slow liquefaction of wort gelatine; and Frankland,[4] in his description of S. liquefaciens, states that it liquefies gelatine fairly rapidly. This action of the three yeasts indicates the excretion of proteolytic enzymes.

Though the statement relative to the extraction of a proteolytic enzyme from yeast is made of pressed yeast, no particular species being named, and there are various pressed yeasts, yet only in the three cases cited has the direct liquefaction of gelatine been noted.

EXPERIMENTS.

Among some wort gelatine yeast cultures I found one which had liquefied the gelatine. On examining the culture it proved to be contaminated by another yeast from the air. The yeasts were separated, and when grown apart, the "wild" yeast was found to be the one which caused the liquefaction. Cultures were made into both the ordinary beef broth gelatine and wort gelatine[5] to determine the constancy of this characteristic of the yeast. Tube and plate cultures of both kinds of gelatine showed liquefaction, the wort gelatine, however, being liquefied sooner than the beef gelatine. From thirty to forty days were required to liquefy a tube containing 6 cc. wort gelatine. The liquefaction was not uniform, even when conditions of media and temperature were alike. Wort gelatine plate cultures became liquefied in about two weeks. These results show undoubtedly the excretion of a proteolytic enzyme by the yeast.

Investigations conducted by Fermi[6] have shown that antiseptics in small amounts are not injurious to enzymes. This property is taken advantage of in the testing for enzymes, and also in determining, relatively, their strength. Water is saturated with thymol to which 5 per cent. of gelatine is added, then placed on a water bath until the gelatine is dissolved, after which 10 cc. are placed in tubes. These are ready for use as soon as the gelatine sets.[7]

To test the strength of the enzyme produced by the yeast, I obtained extracts by filtering the liquefied gelatine from tube cultures. In the first experiment 3 cc. of the extract were used in each tube of thymol gelatine

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[4] Saccardo, P. A. Sylloge Fungorum, Vol. VIII, pp. 916–922.
[5] Wort to which is added 7% gelatine. The wort had .23% acid, estimated as lactic.
[6] Lafar, F. Technical Mycology, Vol. I, 1898, p. 300.
[7] Same as ref. 6.

and a small amount of thymol added to the extract to prevent any further development of the yeast. The liquefaction of the thymol gelatine did not run quite uniformly: In twenty-five days one tube had 8 cc. gelatine liquefied, another had 7½ cc., while a third had 7¼ cc. A second set having extract from cultures six weeks old, in ten days, one liquefied 2 cc. gelatine, a second one 2.2 cc., and a third one 2.5 cc.

Wort in which yeast had been grown for ten days was filtered and 3 cc. of the filtrate used in thymol gelatine tubes, but this was very weak in enzyme. In ten days a cup-shaped depression was formed in the top of the gelatine, but no further action could be discerned. Both the wort gelatine and wort extracts were turbid when placed in the thymol gelatine. It required eight days for the wort extract to become clear and ten days for the wort gelatine extract.

As has been said already, the proteolytic enzymes are of two kinds, the peptic and the tryptic, the pepsin of the gastric juice and the trypsin of the pancreatic juice being taken as types. Besides differing in their decomposition products, they differ in other respects. Pepsin can act only in the presence of dilute acid and is injured by the presence of even a small quantity of the alkaline salt, Na_2CO_3, which is most favorable to the action of trypsin. Trypsin can also act in neutral or slightly acid solutions. A neutral salt in solution is deleterious to both enzymes, but especially so to pepsin, though according to Edkins[8] trypsin is aided by the presence of from 1 to 2 per cent. NaCl, though greatly retarded by 8 per cent. The vegetable trypsins which have been investigated are most active in faintly acid solutions.

In determining the kind of ferment, whether of a peptic or tryptic nature, the thymol gelatine was used for control, and the thymol gelatine with 1 per cent. NaCl, and 1 per cent. Na_2CO_3 added. Tubes of egg albumen were also used.

The following table shows the result of the experiment:

[8] Green, J. R. Fermentation, 1899, p. 193.

S. LIQUEFACIENS EXTRACT.

Experiment.	Age of Culture.	No. cc. Extract.	Time of Clearing.	Time of Liquefaction.	No. cc. Gelatine Lique.
Thymol gelatine	52 days.	2.5	6 days.	17 days.	5.50
Thymol gelatine + 1% NaCl	52 days.	2.5	3 days.	17 days.	6.00
Thymol gelatine + 1% Na_2CO_3	52 days.	2.5	4 days.	17 days.	2.70
Thymol gelatine	50 days.	1.5	1½ days.	17 days.	4.50
Thymol gelatine + 1% NaCl	50 days.	1.5	5 days.	17 days.	4.75
Thymol gelatine + 1% Na_2CO_3	50 days.	1.5	3 days.	17 days.	1.50
Thymol gelatine	40 days.	1.5	4 days.	17 days.	5.00
Thymol gelatine + 1% NaCl	40 days.	1.5	3 days.	17 days.	7.00
Thymol gelatine + 1% Na_2CO_3	40 days.	1.5	2 days.	17 days.	1.75
Egg albumen	52 days.	2.5	6 days.	17 days.	1.00
Egg albumen	50 days.	1.5	8 days.	17 days.	Cup-shaped depression.

Average—T. g., 5.00; T. g. + 1% NaCl, 5.92; T. g. + 1% Na_2CO_3, 1.98.

As indicated in the table, the presence of Na_2CO_3 seems to aid in the enzymic action, as the liquefaction was greater in each case when this was present than in the tubes without any salt. The extract in all the tubes, with the exception of that containing Na_2CO_3 gave a slightly acid reaction. The Na_2CO_3 seemed to hinder the action somewhat, as that was so much lower than either of the others.

In the work of Hahn,[9] and of Hahn and Geret,[10] it would seem as if they draw conclusions in regard to the presence of proteolytic enzymes in pressed yeast from somewhat indefinite causes. In the one case Hahn used pressed yeast, mixing it with *kieselguhr* and squeezing from it a liquid in the same manner as Büchner extracted his zymase. This liquid was treated with chloroform, to which was added gelatine and a trace of phenol. The extract liquefied the gelatine. Then Hahn and Geret used extract obtained in the same way with chloroform alone, keeping the solution at 37° C. for several weeks. The chloroform served to precipitate the proteids and keep the solution free from living organisms. A bulky precipitate was formed, which gradually disappeared. The liquid again became turbid, the second turbidity being due to the formation of amido compounds (tyrosin and leucin). From these experiments they conclude that they have extracted a proteolytic enzyme from the yeast. If the pressed yeast consisted of yeast only, there would be no question in regard to the results, but pressed yeast always contains a relatively large number of bacteria and a few moulds. Among the bacteria one is pretty sure to find some liquefiers.

To test for the presence of liquefiers I made some gelatine plate cultures from pressed yeast; and a description of one which contained only one colony of a liquefying bacterium will serve to indicate the power of the enzyme which was excreted. When the liquefying colony was first noted it was ½ mm. in diameter but at the end of twelve hours it had liquefied a spot 19 mm. in diameter; in twenty-three hours the spot had increased to forty-seven mm. in diameter and in forty-eight hours the gelatine of the entire plate was liquefied. Cultures were made into beef gelatine and the gelatine (6 cc.) was liquefied in forty-eight hours. The liquefied gelatine from a tube was filtered, and the filtrate used to determine enzymic action of the bacteria as in the former experiments for the yeast. At the same time 60 grams of pressed yeast were mixed with

[9] Hahn, M. Ber. d. deut. chem. Gesell., 1898, No. 2, pp. 200-201.
[10] Hahn, M., and Geret, L., l. c., pp. 202-205.

emery and ground in a mortar for an hour. Then a mash of the mixture was made with 20 cc. distilled water. The mash was put in a press and squeezed, the extract being filtered. The extract was used as in the former experiments, in addition to which 10 cc. were heated to 45° C. to precipitate the proteid matter.

The same quantity of pressed yeast was made into a mash with 20 cc. dis. water, saturated with thymol, but without any previous grinding. The extract from this was used in the same manner as that obtained from the ground yeast. This was allowed to stand for one hour, then pressed and filtered, the filtrate used as in the former experiment.

The purpose of this experiment was to determine if it be necessary to crush the yeast cells in order to obtain the enzyme. The following table shows the results obtained in the various experiments.

COMPRESSED YEAST EXTRACT, GROUND.

Experiment.	Age of Culture.	No. cc. Extract.	Time of Clearing.	Time of Liquefaction.	No. cc. Gelatine Liq.
Thymol gelatine	....	1.5	....	13 days.	2.0
Thymol gelatine + 1% NaCl	....	1.5	....	13 days.	3.0
Thymol gelatine + 1% Na_2CO_3	....	1.5	....	13 days.	3.0
Thymol gelatine	....	5.0	11 days.	17 days.	2.0
Thymol gelatine + 1% NaCl	....	5.0	Not clear.	17 days.	2.5
Thymol gelatine + 1% Na_2CO_3	....	5 0	Not clear.	17 days.	3.0
Egg albumen	....	1.5	....	13 days.	Shallow depression.
Egg albumen	....	5.0	Not clear.	17 days.	1.0
Yeast solution, heated to 45° C.	....	10.0	Not clear.	17 days.	No apparent action.

Average—T. g., 2.0; T. g. + NaCl, 2.75; T. g. + Na_2CO_3, 3.00.

COMPRESSED YEAST, WITHOUT GRINDING.

Experiment.	Age of Culture.	No. cc. Extract.	Time of Clearing.	Time of Liquefaction.	No. cc. Gelatine Liq.
Thymol gelatine	....	5.0	Clear at start.	8 days.	2.0
Thymol gelatine + 1% NaCl	....	5.0	Clear at start.	8 days.	1.0
Thymol gelatine + 1% Na_2CO_3	....	5.0	Clear at start.	8 days.	3.5
Yeast solution	....	10.0	Clear at start.	8 days.	No apparent action.

BACTERIAL EXTRACT.

Experiment.	Age of Culture.	No. cc. Extract.	Time of Clearing.	Time of Liquefaction.	No. cc. Gelatine Liq.
Thymol gelatine	4 days.	1.5	Clear at start.	13 days.	2.25
Thymol gelatine + 1% NaCl	4 days.	1.5	Clear at start.	13 days.	2.00
Thymol gelatine + 1% Na_2CO_3	4 days.	1.5	Clear at start.	13 days.	2.75
Thymol gelatine	7 days.	3.0	Clear at start.	8 days.	4.00
Thymol gelatine + 1% NaCl	7 days.	3.0	Clear at start.	8 days.	1.75
Thymol gelatine + 1% Na_2CO_3	7 days.	3.0	Clear at start.	8 days.	3.00

Average—T. g., 3.12; T. g. + NaCl, 1.87; T. g. + Na_2CO_3, 2.87.

The results of the experiments show that the pure yeast excretes a proteolytic enzyme that is fairly active, and from the fact that it works in the presence of neutral and alkaline salts, it must be of a tryptic nature. It seems to be of the same nature as the trypsin extracted by Edkins, since it works best in the presence of NaCl.

The experiments on the compressed yeast and the bacteria obtained from the compressed yeast show undoubtedly the presence of an enzyme, but the indications point more strongly to a bacterial than to a yeast origin, since it was not necessary to break the yeast cells before the pressing in obtaining the enzyme, and also, since in experience with pure yeast cultures, only three cases have been noted in which any perceptible enzymic action took place. Then the bacterial extract was very strong, so that though only a comparatively small number of bacteria are present in the compressed yeast as compared with the yeast, the activity of the extract would be accounted for. Then again though the bacterial and compressed yeast extracts did not act uniformly, they showed the same peculiarity in the greater activity of the extract in the presence of Na_2CO_3. Work with a mixture of organisms is always open to the doubt in regard to the action of each organism.

DESCRIPTION OF THE YEAST.

The cells of this species are very variable in shape, being round, elliptic, elongated and irregular, slender at one end and widening out toward the other, or showing projections from the sides (Ill. 1). These irregularities occurring to the greatest extent in wort gelatine cultures (Ill. 2). In wort the cells become much elongated and are in long chains (Ill. 3), while in lactose solution the round cells predominate and occur mostly in pairs. Occasionally giant cells are found in the cultures. The cells which are round in a lactose solution, when placed in wort in a moist chamber, lengthen inside of twenty-four hours. (Ills. 4, 5.)

They vary in size, the round cells averaging 3.3 μ in diameter, while the average of the elongated are 3.3 μ by 10 μ.

This yeast does not ferment sucrose or lactose. It forms a fairly heavy sediment in the sucrose, but only a slight growth in the lactose. In dextrose it required six days for fermentation to start and twenty-four hours to form 3 cc. gas. In wort, which contains maltose, fermentation started in four days, and 25 cc. of gas were formed in three days, when the culture was kept at room temperature, but at 30° C., gas is given off in twenty-four hours.

In wort gelatine tubes the growth tapers from the surface along the needle track, having fine line of growth radiating from the main growth, then the gelatine gradually breaks down with the liquefaction.

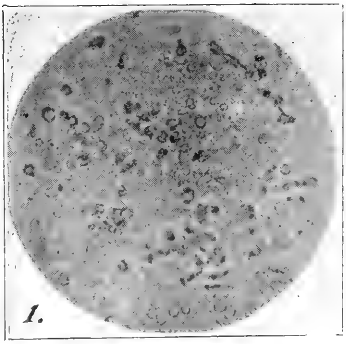
The colonies at first are rather thick in the center with filaments radiating from the central mass. When liquefaction begins, which is inside of three days, the central mass breaks down and spreads as a sort of mycelial mass over the plate, resembling very strongly a mould growth when seen under the microscope; Ills. 6, 7, 8 show successive stages in the growth and liquefaction.

The species is undoubtedly S. liquefaciens, as described in Saccardo,[11] the cells showing the same variations and varying only slightly in size from that description.

EXPLANATION OF ILLUSTRATIONS.

1. Ten days' growth in wort. x320.
2. Two weeks' growth in wort gelatine. x450.
3. Sixteen days' growth in wort gelatine. x320.
4. Twenty-four hours' growth in wort in moist chamber. x334.
5. Round cells from lactose solution in moist charmber. x320.
6. Colony grown in wort gelatine, three days old. x30.
7. Colony grown in wort gelatine, four days old. x35.
8. Colony grown in wort gelatine, four days old. x35.

[11] Saccardo, P. A. Sylloge Fungorum, Vol. VIII, pp. 916–922.



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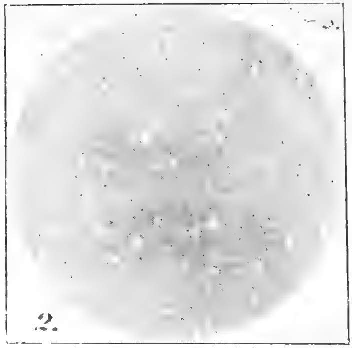

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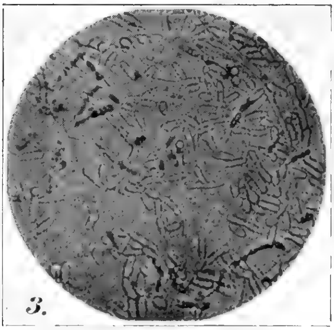

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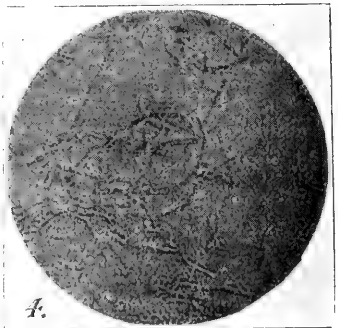

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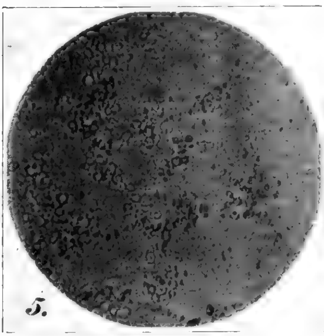

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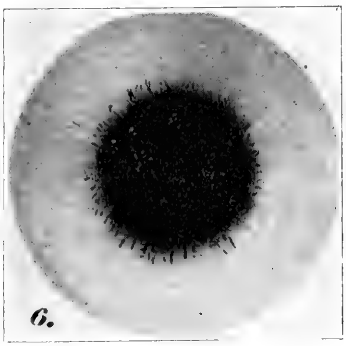

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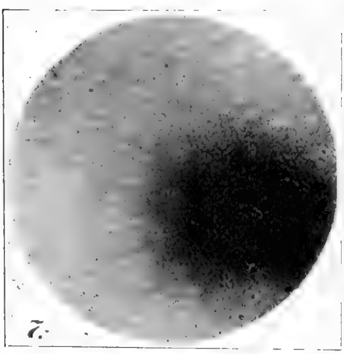

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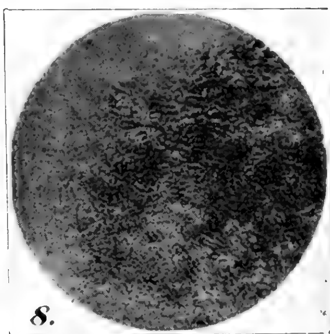


8.

Saccharomyces anomalus Hansen(?)

By Katherine E. Golden.

In his investigations upon spore formation in yeasts Hansen found three typical groups, these three differing either in the form of the spores or in their mode of germination. The third type is furnished by S. anomalus, the spores of which are hemispherical in form, having a projecting rim around the flattened surface. The other two types are spherical in form, but differ in their mode of germination. Hansen found this species in an impure Bavarian brewery yeast, and after he had called attention to the peculiar spores, they were also observed by Holm, Lindner and Will,[1] who likewise found them in impure brewery yeast. These investigators did not determine whether the peculiar spores which they observed belonged to Hansen's S. anomalus or to allied species. Bay[2] gives the habitat as impure brewery yeast and grapes, as does Kayser.[3]

Hansen's[4] description of the yeast is very brief, as is also the description by Jörgensen[5] and that given in Saccardo[6] so that the form of the spores is the most characteristic feature.

A yeast which develops the same form of spores, I found associated with another yeast on the skin of lemon. This is a new habitat for the yeast, and I can find no mention of any such yeast occurring in this country.

The cells are round or oval, occurring either singly or in pairs, though occasionally in a vigorous growth in wort colonies consisting of many cells are found (photograph 1). The cells are very small, measuring 2.4 μ in breadth by 3.3 μ in length for the small oval ones to 6.6 μ in diameter for the cells containing spores (seen in photograph 2).

In wort gelatine plate cultures the colonies are of a dull, grayish white color, round, with rather even outline. They grow rather slowly under the best conditions. The photograph (3) shows a forty-eight-hours' growth. The wort gelatine plates seem to offer better conditions for the

[1] Jörgensen, A. Micro-Organisms and Fermentation, 1893, p. 182.
[2] Bay, J. C. Am. Naturalist, Vol. XXVII, 1893, pp. 685–696.
[3] Kayser, E. Les Levures, p. 104.
[4] Hansen, E. C. Central. f. Bakt., Bd. XIII, 1893, pp. 101–102.
[5] L. c., pp. 181–182.
[6] Saccardo, P. A. Sylloge Fungorum, Vol. VIII, pp. 216–228.

formation of spores than any of the other cultures, spores being found in four days at room temperature.

In both wort and beef broth gelatine tube cultures the growth is practically the same. The growth has a dry appearance and forms a dense mass at the needle puncture, without any tendency to spread. The growth tapers gradually from the surface along the needle track until at the bottom of the tube it is just perceptible. It has a characteristic crinkly appearance along its whole length.

Cultures in Pasteur solution, with 5 per cent. sucrose, lactose and dextrose, were made in fermentation tubes, and also in wort which contains maltose. In sucrose no fermentation occurred; there was a heavy growth, however, which caused a strong turbidity of the liquid in the bulb and a heavy sediment; the liquid in the tube remained clear. A film was formed which extended up the sides of the tube. After five days no spores were found either in the film nor in the sediment. Only a very slight growth occurred in the lactose solution, this forming a delicate film and a slight sediment. No gas was formed. The cells in lactose occur singly or in pairs and appear poorly nurtured (photograph 4). In the dextrose solution the growth was vigorous, forming a heavy sediment. Fermentation commenced in four days, and in twenty-four hours 5 cc. of gas were formed. In this, as in the sucrose solution, a strong film was formed. No spores were found in the film nor in the sediment even after seven days' growth. In the wort the fermentation was much more vigorous than in the dextrose, 10 cc. of gas being formed in the time that only 5 cc. were formed in the dextrose solution. Even before fermentation ceased a film formed in spots on the surface. In the wort a delicate ethereal odor is generated, which is very pleasant. Spores were just beginning to form in the film and sediment in eleven days.

Spores formed more readily in a wort gelatine plate culture than even in the regulation manner on a gypsum block. In the plate they formed invariably in four days, not to any great extent, but sufficient to be found in every microscopic examination. The cells in which the spores form are large, and just before the formation the protoplasm becomes very granular and refractive. As the culture ages and more spores are formed they are found free from the cell wall and in groups ranging from two to fourteen in number. Spores can be seen in photographs 5 and 6.

It is not quite certain whether this is the same species as Hansen's S.

anomalus, for the prominent characteristics in the description of that yeast are the peculiar form of the spores and their ready formation in both the film and sediment during fermentation. The shape of the spores in the yeast described is the same as that of Hansen's, but the earliest period at which spores were formed in fermenting wort was eleven days, and then very sparingly. In the other solutions used, no spores were formed even after three weeks' growth. Then no mention is made of their rapid formation in wort gelatine plates, and yet they form there very readily.

Taking into consideration the characteristics which are described by Hansen for S. anomalus—spore formation, size and shape of cells, and odor generated during fermentation—and comparing them with those of the yeast described, they agree fairly closely, but the characteristics which are not noticed seem to be sufficiently prominent to not have escaped attention if they existed in S. anomalus. Those are lack of fermentation of sucrose and the nonformation of spores in liquids other than wort. To me it seems that the two yeasts are similar, and the failure to note certain characteristics can be accounted for by the brevity of the original description.

EXPLANATION OF ILLUSTRATIONS.

1. Cells grown in beer wort. x700.

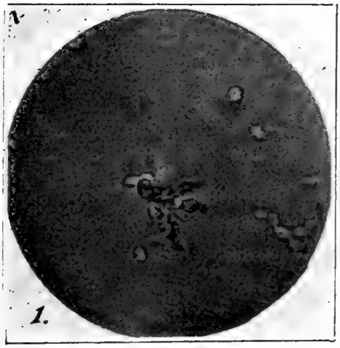
2. Eight days' growth in Pasteur solution containing 5 per cent. sucrose. x700.

3. Forty-eight hours' growth on wort gelatine plate. x30.

4. Ten days' growth in Pasteur solution containing 5 per cent. lactose. x320.

5. Cells showing spore development, from wort gelatine plate, ten days' growth. x700.

6. Cells showing spore development, from wort gelatine plate, two weeks old. x700.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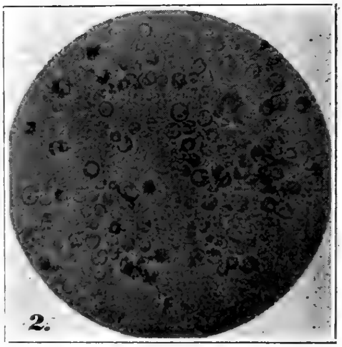
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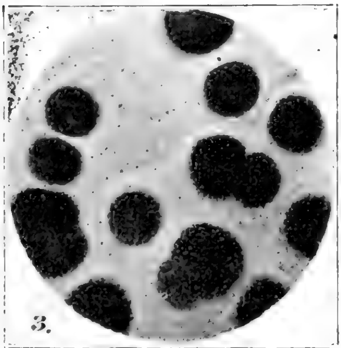
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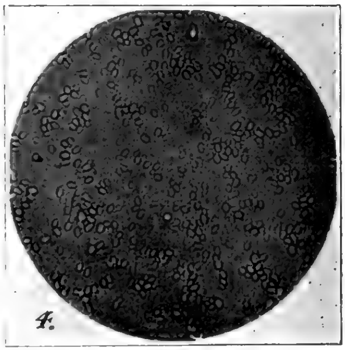
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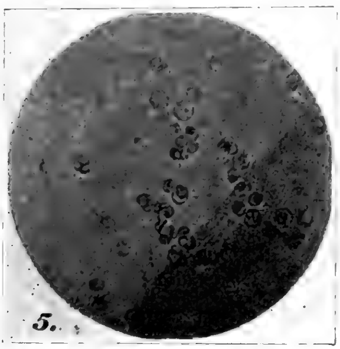
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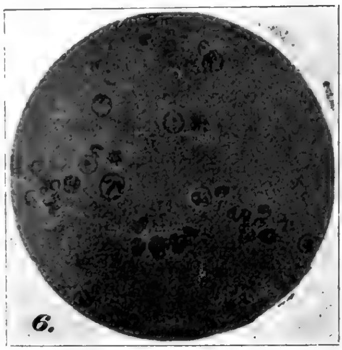
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Some Problems in Corallorhiza.

By M. B. Thomas.

Some recent discussions regarding the relation of endophytic mycelium to the roots of certain orchids and allied plants has suggested an investigation into this condition in the Orchidaceae, and the results show that out of fifty species of orchids examined all present this relation in a varying degree. The very peculiar root system of the plants of this family may be accounted for by the influence of this semi-parasitic condition.

In corallorhiza, no doubt most of the nutrient material taken in is through the agency of these very abundant hyphae, while in the cypripediums, though present, the hyphae do not play a very conspicuous part in the absorption of food by the plant.

The great abundance of the hyphae in certain green orchids leads us to infer that the presence of these threads alone is not sufficient to account for the very remarkable phenomena in certain colorless orchids like corallorhiza, etc.

In my judgment, other and less obvious changes will yet be determined that will assist in accounting for the very remarkable life history of corallorhiza.

The paper deals with some of the problems along this line and the results will be published elsewhere.

The Disappearance of Sedum ternatum.

By M. B. Thomas.

Attention is called to the very unusual condition of a plant in which modifications for adaptation to its peculiar environment failed to protect it from the severity of the fall and winter of 1898-9. Sedum ternatum Michx., a plant found in several localities previous to that time, completely disappeared, so that no trace of it remained in the local flora of Crawfordsville.

The paper, which is to be published in full elsewhere, deals with the history of adaptation in this plant.

A Preliminary Report on the Eye of the Mole (Scalops aquaticus machrinus).

By James Rollin Slonaker.

It is a general belief with many people that the mole does not have eyes. This is possibly due to the fact that the eyes are not readily seen and that an animal living habitually in the ground would have little or no use for organs of sight. But this, like many other common ideas, is wrong, for the mole has not only a well-defined eye, but one which is readily observed on parting the fur at the right place. It is seen as a dark area covered by the skin and true eyelids. The latter, however, are rudimentary and the cleft between them so small that it is practically never open enough to admit light. (Fig. 1.)

From this fact alone one could safely conclude that the power of sight in the mole is no more than to distinguish between light and darkness. But when the eye itself is examined this conclusion is well substantiated.

Comparing the mole eye with a normal mammalian eye it is found to be quite degenerate. The stages of degeneration seem to be in the following manner:

The eye decreases materially in size. This reduction diminishes the size of the aqueous and vitreous chambers until in some eyes they are wholly wanting. This allows the retina to collapse, causing the inner layers to become more or less jumbled together. Each of the layers may, however, be made out as is shown in Figs. 2 and 3.

The lens is much modified in size and shape in different eyes. Owing to the great diversity of pressure exerted by the shrinking eye the lens takes a variety of forms which may be decidedly different in eyes taken from the same animal. This is shown in Figs. 2 and 3, representing the right and left eye respectively, from the same animal. On magnifying the lens the cells are seen to resemble cartilage more than typical lens cells. (Figs. 4 and 5.) The histological degeneracy of the lens has thus gone much farther than one would at first suspect.

Ritter[1] and Rabl[2], in describing the development of the mole lens say

[1] C. Ritter, Die Linse des Maulwurfs. Arch. f. Micr. Anat. u. Entwl., Bd. 53, Heft III, p. 397.

[2] Carl Rabl, Ueber den Bau und die Entwicklung der Linse. Zeitschr. f. Wis. Zool., Bd. 67, Heft 1, 1899, p. 63.

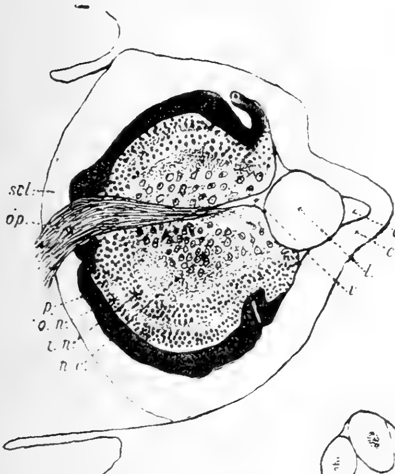


Fig. 3

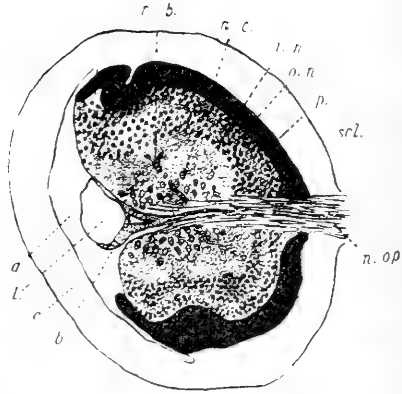


Fig. 2.

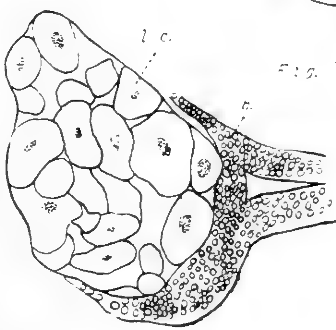
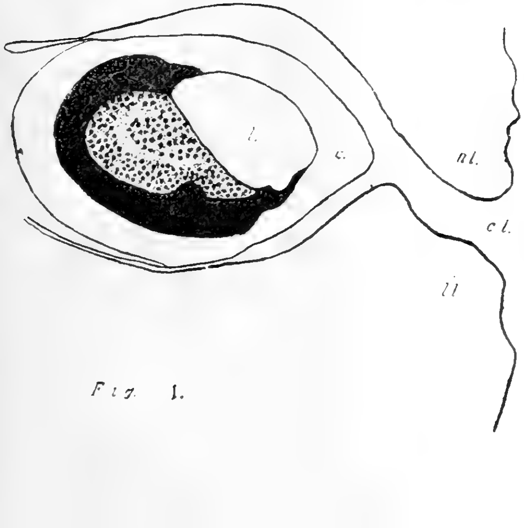


Fig. 5



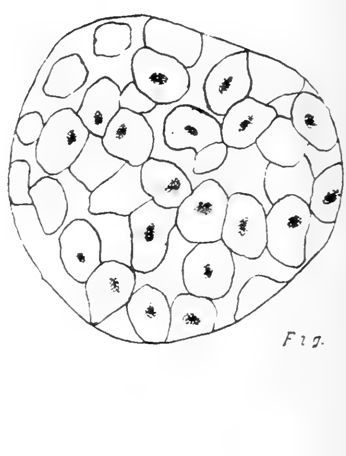


Fig. 4.

Fig. 1.

that it is similar to the mammalian type in its early stages, but the later stages are arrested, and in the adult the typical lens cells have degenerated to a form as above described.

The finer histological structures and relations of the different cells will be presented in a later paper.

The function of such an eye as this may be reasonably conceived when we consider the composition and shape of the lens, the almost closed lids and the closely crowded condition of the retina. The power of sight would doubtless extend little if any beyond the ability of distinguishing between light and darkness.

EXPLANATION OF FIGURES.

All the figures are semi-diagrammatic camera drawings of sections from the mole eye.

ABBREVIATIONS.

a. Aqueous chamber.
b. Blood vessel.
c. Cornea.
cl. Cleft between eyelids.
i. n. Inner nuclear layer.
o. n. Outer nuclear layer.
n. c. Nuclear or ganglion cell layer.
l. Lens.
ll. Lower eyelid.
ul. Upper eyelid.
r. b. Retinal blood vessel.
p. Pigment layer.
v. Vitreous chamber.
scl. Sclerotic coat.
n. op. Optic nerve.
l. c. Lens cells.

Fig. 1.—Vertical section through eye and lids showing the cleft between the lids. The section did not pass through the center of the eye. x48.

Fig. 2.—Vertical section passing through center of nerve and lens. The thickness of the different layers is correctly represented, but the cells are diagrammatic. x48.

Fig. 3.—Horizontal section through the left eye from the same animal as Fig. 2. The cornea is folded, due to the hardening fluid. x48.

Fig. 4.—Enlarged view of lens from the same eye as Fig. 3. The peculiar cartilage-like cells are shown. x270.

Fig. 5.—Enlarged view of lens from the same eye as Fig. 2. x270.

Notes on Indiana Birds.

By Amos W. Butler.

The following notes are given here in order that they may be placed on record. In them are included such records of special interest as have been brought to my attention since the publication of my report on "The Birds of Indiana," at the beginning of 1897. In them, it will be observed, are added two species to the list of birds of this State. These are the Caspian Tern and Bachman's Warbler. There are also some interesting notes on the appearance of the Wild Pigeon.

AYTHYA VALLISNERIA (Wils.).

Canvas-back Duck.—A male and female were killed in the marsh at English Lake, Indiana, November 4, 1899. Never known to have been taken there in the fall before.

A single one was seen at the same place November 24, 1899. (Ruthven Deane.)

CLANGULA HYEMALIS (LINN.).

Old Squaw Duck.—February 12, 1899, a flock of thirteen Old Squaws alighted in the water where ice was being cut at English Lake, and all were killed. (Ruthven Deane.)

October 29, 1889, a specimen was taken at Calumet Heights, Indiana. This is a very early record.

LOXIA CURVIROSTRA MINOR (BREHM).

American Crossbill.—Dr. Stanley Coulter reports at least two dozen on Purdue University Campus November 3, 1898.

LOXIA LEUCOPTERA (Gmel.).

White-winged Crossbill.—Reported quite abundant around Chicago in the past two weeks. (Ruthven Deane, in Epist. 11-26-99.)

Reported from near Richmond, where a male was seen May 1, 1899, by Joseph F. Honecker.

A male was found dead beneath the electric wires at Greensburg, Indiana, November 7, 1899, by a little colored boy, who brought it to Prof. Geo. L. Roberts, in whose collection it now is. Upon investigation, a few minutes thereafter, Professor Roberts found six or eight others among the maple trees in a yard near by.

ECTOPISTES MIGRATORIUS (LINN.).

Passenger Pigeon.—Six were seen July 10, 1899, at St. Peters, Franklin County, Indiana; also found four nests near Oak Forest, Indiana.

October 23, 1898, a flock of sixty-eight was seen near Springfield in the same county. (Jos. F. Honecker.)

One mounted by Beasley & Parr, of Lebanon, was killed by Frank Young, Willson P. O., Shelby County, Indiana, near that place, about September 24, 1898. It was in company with two doves in a patch of wild hemp when found. The specimen is in the possession of W. I. Patterson, Shelbyville, Indiana.

Joseph F. Honecker has reported these birds several times from the vicinity of Oak Forest, Franklin County. Under date of July 13, 1898, he says:

"On June 13, 1898, I found a place where about forty wild pigeons were roosting in a woods about one-half mile from Oak Forest, Franklin County, Indiana. The owner of the woods informed me that the pigeons stayed there for the last three years, roosting on a maple tree which was blown down by a severe wind storm June 28 1898. The pigeons are, I think, staying in that same woods yet, but where I am unable to find out. The pigeons are breeding in the woods, as I found fourteen nests with nestlings. This is the third flock of wild pigeons I have seen in this county in the last five years."

STERNA TSCHEGRAVA (LEPECH).

Caspian Tern.—Mr. J. Grafton Parker, Jr., reports the identification of five specimens of this Tern at Miller's, Indiana, in August, 1898. None were taken.

Mr. F. M. Woodruff, of Chicago, says the Caspian Tern is not a rare bird on the lake in the early fall. "A few are seen each year at Miller's, Indiana. They are very shy, but I have managed to obtain four of them."

HELMINTHOPHILA BACHMANI (AUD.).

Bachman's Warbler.—A female of this rare warbler was taken May 2, 1899, near Greensburg, Indiana, by Mr. W. F. West. The captor says: "It had no song. It was taken from the lower branches of a large elm tree, situated on the bank of a small stream which flows through an open woods." The following is the description: Forehead, sides of head, upper neck and breast, bright yellow; crown and band across neck, black; belly and under-tail coverts, whitish; above, back of head and neck, grayish; back, wing coverts and edge of quills, tinged with olive green; upper tail coverts, bright olive green; wings, grayish; tail apparently same color; but two feathers, however, remain for determination. Length, 4.50; tail, about 2.00; wing, 2.37. Male.—Greensburg, Indiana, May 2, 1899, Col. W. F. West.

It is interesting to note this extralimital record of this rare bird. Its range is South America and the Gulf States west to Louisiana; Cuba in winter. It has been taken as far north as southern Virginia and Arkansas.

Biological Conditions of Round and Shriner Lakes, Whitley County, Ind.

By E. B. Williamson.

Whitley County is situated in the northeastern part of Indiana. It is bounded on the east by Allen County, of which Fort Wayne is the county seat; Columbia City, situated very nearly in the center of the county, is the county seat of Whitley County. Round, Shriner and Cedar lakes lie in the northern part of the county, above seven miles from Columbia City. Shriner and Cedar lakes lie parallel to each other, directly west of Round Lake, into which they empty their waters. Round Lake is drained into

Thorn Creek, which leaves the lake on the south, passing into Blue River, then into Eel River, and so into the Wabash.

The outlet from Shriner Lake to Round Lake is a narrow artificial channel. The connection between Cedar Lake and Round Lake is formed by a marsh, grown up with cat-tail flag *(Typha latifolia)*, button-bush *(Cephalanthus occidentalis)*, swamp loosestrife *(Decodon verticillatus)*, and a variety of other marsh plants, with occasional stretches of open water.

But little time was spent about Cedar Lake. Its shores are covered with underbrush, and the bottom of the lake is so soft and, near the shore, so encumbered with tree trunks and branches that collecting is very difficult. A number of dragonflies were taken, but nothing was found here that was not observed at Round and Shriner.

Shriner Lake is one and one-quarter miles long, east and west, and one-quarter of a mile wide.* A small stream, which is dry most of the year, enters the lake at its southwestern part; but springs are almost the entire source of water supply. The temperature for some points at the bottom of the lake is as low as 50 degrees. The shores are sandy, and, with the exception of a portion of the northern part, solid and firm. Generally the bottom slopes rapidly from the shore line of deep water. The greatest depth is over seventy feet. Back from the water line the shores rise in low bluffs, covered with oak, maple and beech timber. A few sycamores and cottonwoods grow near the water's edge. About the western and northwestern parts of the lake the land has been cleared, and is now under cultivation.

The flora of the region is rich. Among the more conspicuous plants the following may be mentioned: Water-lily *(Nymphæa odorata)*, spatter-dock *(Nuphar advena)*, water-shield *(Brasenia peltata)*, bladderwort *(Utricularia vulgaris)*, stiff white water-crowfoot *(Bidens Beckii)*, water-weed *(Elodea Canadensis)*, cat-tail flag *(Typha latifolia)*, arrow-head *(Sagittaria)*, pickerel-weed *(Pontederia)*, several species of pondweeds *(Potamogeton)*, pipewort *(Eriocaulon septangulare)*, dulichium *(Dulichium arundinaceum)*, several species of spike-rush *(Eleocharis)*, several species of bullrushes (among them *S. atrovirens*, *S. lineatus*, *S. Americanus*, and *S. lacustris*), beak rush *(Rhynchospora glomerata)*, bog rush *(Juncus Canadensis* var. *longicaudatus)*, and several species of *Cyperus*. Thistles, goldenrods, asters, mints, knotweeds *(Polygonum)*, and blue flag *(Iris)*, with a variety

*For this and a number of other facts I am indebted to the Biennial Report of Mr. P. H. Kirsch, State Fish Commissioner of Indiana, for the years 1895 and '96.

of grasses and smaller sedges cover the shores. In adjoining woodlands I have found two species of orchids, the nodding pogonia (P. trianthophora) and the coral-root *(Corallorhiza odontorhiza)*.

Round Lake is seven-eighths of a mile long and one-half of a mile wide. The water supply is derived from Cedar and Shriner lakes. Round Lake is shallower and warmer than Shriner and the water is less clear. Excepting small stretches of sandy beach along the northeastern and southern sides, the shores of the lake are soft and miry. The dredging of Thorn Creek has lowered the lake until at several places at a distance from shore the potamogetons reach the surface of the water. Lowering the lake five feet more will fill it with sand bars or even reduce it to a number of ponds. An extensive tract near the head of Thorn Creek, which five years ago was a swamp, is now under cultivation. Among the farmers of the neighborhood the practice is common of planting artichoke among the spatter-dock where the lowering of the lake has exposed the land. In the fall this is turned over to hogs and their persistent rooting in the soft earth pulverizes and dries the soil most effectually.

The vegetation about Round is ranker even than about Shriner Lake, and spatter-dock *(Nuphar)*, which is rather rare there, almost surrounds this lake. In September, 1897, my friend, Mr. C. C. Deam, of Bluffton, Indiana, found the reversed bladderwort *(Utricularia resupinata)* growing along the western shore. Greater bladderwort *(U. vulgaris)* is abundant, and with potamogetons, eel grass *(Vallisneria)*, hornwort *(Ceratophyllum)* water-milfoil *(Myriophyllum)*, and stiff white water-crowfoot completely clothes the bottom of the shallower parts of the lake.

Not only is the vegetation more luxuriant about Round Lake than about Shriner, but the former lake seems biologically richer in every way. Shriner is a beautiful, deep, clear, blue reservoir of spring water, while Round Lake is a warm, shallow basin, surrounded by marshes, and containing the overflow of two lakes, and the drainage of neighboring woods and fields. Mr. Kirsch has recorded twenty-one species of fish for Shriner Lake and twenty-five species for Round Lake. I have not observed any crawfish at Shriner Lake, but about the shores of Round Lake the burrows and chimneys of *Cambarus diogenes* are common. While the two lakes have each furnished about the same number of species of dragonflies, these insects are usually much more numerous about Round than about Shriner.

Of the vertebrates of this region the following species may be noted: Mammals—moles, shrews and mice are common. Gray squirrel *(Sciurus carolinensis)* are rare, fox squirrels *(S. niger* var. *cinereus)* common and red squirrels *(S. hudsonicus)* and chipmunks *(Tamias striatus)* abundant. Minks *(Lutreola vison)*, weasels *(Putorius noveboracensis)* and 'coons *(Procyon lotor)* are common; and woodchucks *(Arctomys monax)* burrow in the hillsides in considerable numbers. Birds: Green herons *(Ardea virescens)* visit the lakes frequently, great blue herons *(Ardea herodias)* rarely; Virginia rails *(Rallus virginianus)* and least bitterns *(Botaurus exilis)* have been occasionally observed. Red-winged blackbirds *(Agelaius phoeniceus)* are very abundant. Summer yellow-birds *(Dendroica aestiva)* nest in numbers in the button-bushes in the marshes. In 1895 long-billed marsh wrens *(Cistothorus palustris)* nested in the vicinity of Round Lake, but during 1898 none were seen or heard. During 1896 a loon *(Urinator imber)* spent the summer at Shriner Lake, where it might have been seen almost any day. Sandpipers *(Actitis macularia)* and killdeers *(Aegialitis vocifera)* are common. An occasional Bartramis sandpiper *(Bartramia longicauda)* is seen in flocks of the latter species. Reptiles: Of the turtles the western painted turtle *(Chrysemys marginata)*, mud turtle *(Aromochelys odorata)* and snapping turtle *(Chelydra serpentina)* were the only species observed. These three are common or abundant. Three species of snakes are often observed about the lakes: Water snake *(Tropidonotus sipedon)*, garter snake *(Eutania sirtalis)* and riband snake *(Eutania saurita)*. The blue lizard *(Eumeces fasciatus)* is not rare in adjoining woodland. Amphibians: Spotted frogs *(Rana virescens)* are very abundant, and bullfrogs *(Rana catesbiana)* rather rare. Fish: An abundance of game and food fish are found in these lakes. Of the two Round Lake is regarded as affording the best fishing grounds. Yellow perch *(Perca flavescens)*, large-mouthed black bass *(Micropterus salmoides)* and a number of species of sunfish *(Lepomis)* are those most usually taken. Catfish, both the yellow cat *(Ameiurus natalis)* and bullhead *(Ameiurus nebulosus)*, and pike *(Lucius lucius)* are more rarely met with. Occasionally the calico bass *(Pomoxis sparoides)* and the warmouth *(Chaenobrythus gulosus)* are taken in considerable numbers about the east end of Shriner Lake. The latter species is called mud bass, and the calico bass is referred to as rock bass by the local fishermen. This confusion of common names is odd for the reason that, while the warmouth *(Chaenobrythus gulosus)* much resembles the rock bass

(Ambloplites rupestris) the calico bass *(Pomoxis sparoides)*, to which the name "rock bass" has been applied, has but little general resemblance to this fish.

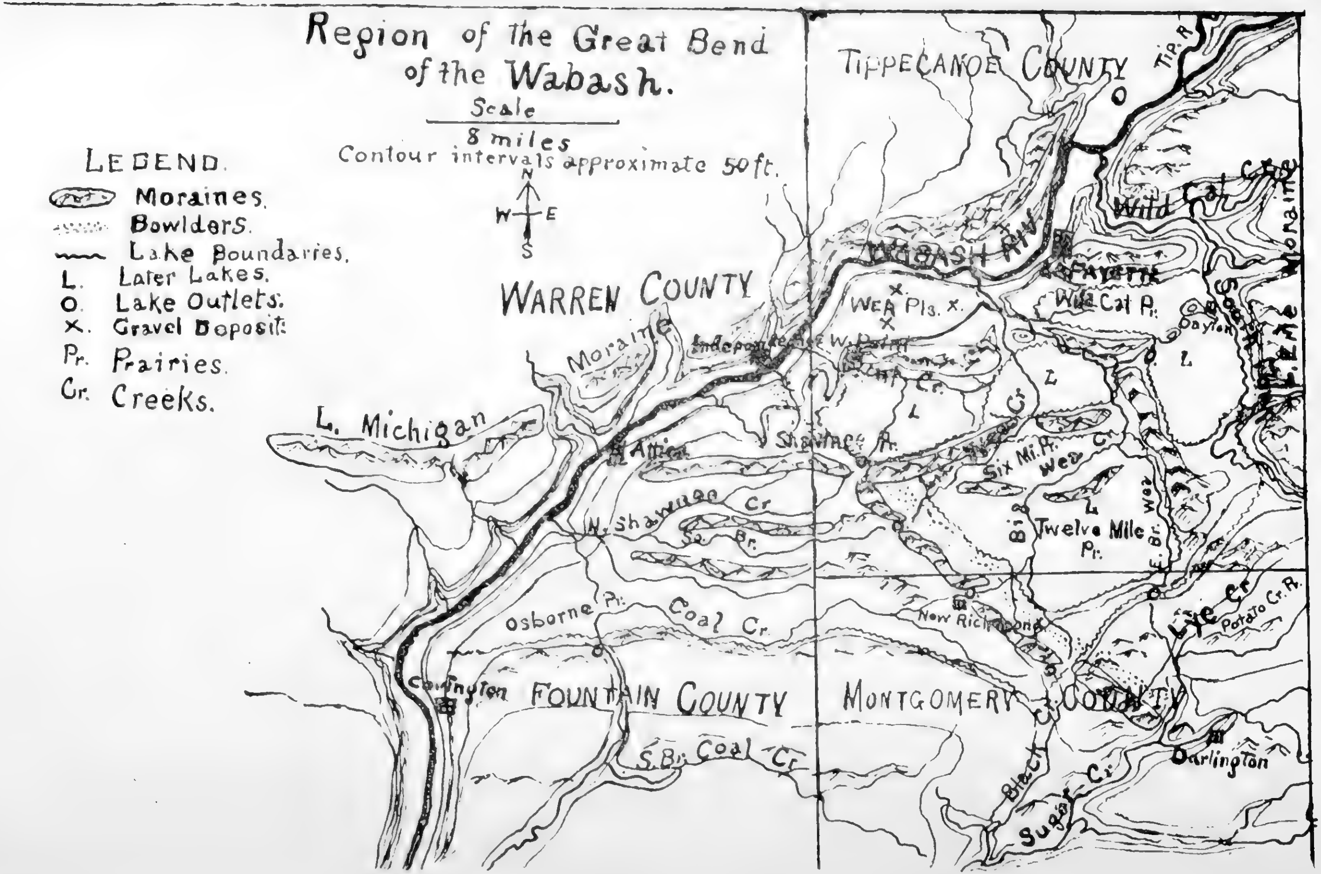
Molluscans are rare about either lake, but are more common about the eastern shores of Round Lake than elsewhere.

Of the insects, Neuroptera, Orthoptera and Diptera are most numerous. Lepidoptera, Coleoptera and Hymenoptera are less conspicuous. The Odonata fauna is the richest and most characteristic. On June 8, 1898, the air was alive with larger species, and in the shore-line grasses and sedges smaller forms swarmed in countless numbers. From May until December they are fully entitled to rank as the most attractive and interesting insects of this region. Strong and fierce, constantly warring among themselves, so far as observed in the perfect-winged state they suffer defeat from only one quarter. In the webs of a species of large black and yellow spider *(Argiope)* I have found the remains of *Argia violacea, Libellula pulchella* and *Mesothemis simplicicollis*. Of the two latter species only very teneral individuals were found so entrapped. Sunfish often dash at Libellulas when they are ovipositing, but I have never seen the dragonflies injured by these attacks.

The only two common names I have heard used in northern Indiana for the insects are "snake-feeders" and "snakedoctors." The belief that they can sting is almost universal. To the good people living about the lakes in Whitley County the occupation of the collector is beyond understanding. From his first appearance till his final departure he is plied with questions, his answers only confirming his questioners in their notions as to his mental instability. Among other questions I may record the following: "Are you getting snake-feeders for bait?" "To eat?" "To use their wings to make picture frames or ornaments?" "Or is there a bounty on them?"

The Eyes of Cambrus Pellucidus from Mammoth Cave.

By F. M. Price.


Region of the Great Bend of the Wabash.
Scale
8 miles
Contour intervals approximate 50 ft.
N
W E
S
LEGEND.
Moraines.
Bowlders.
Lake Boundaries.
L. Later Lakes.
O. Lake Outlets.
X. Gravel Deposit.
Pr. Prairies.
Cr. Creeks.
TIPPECANOE COUNTY
Tip. R.
WARREN COUNTY
FOUNTAIN COUNTY
MONTGOMERY COUNTY
Wabash Riv.
La Fayette
Wild Cat Cr.
Wild Cat Pr.
Moraine
Wea Pls.
Dayton
Moraine
L. Michigan
Attica
Shawnee Pr.
N. Shawnee Cr.
So. Br.
Six Mi. Pr.
Wea Cr.
Twelve Mile Pr.
E. Br. Wea
Big Cr.
Osborne Pr.
Coal Cr.
New Richmond
Lye Cr.
Potato Cr. R.
Covington
S. Br. Coal Cr.
Black Cr.
Sugar Cr.
Darlington

Cortex Cells of the Mouse's Brain.

By D. M. Dennis.

The Physical Geography of the Region of the Great Bend of the Wabash.

By William A. McBeth.

The region here considered embraces most of the area of Tippecanoe, the north half of Fountain and Montgomery and the southeastern border of Warren counties, lying in that part of Indiana where the Wabash River, after traversing the State nearly its entire width, turns abruptly to the south, which direction it follows through the remainder of its course.

The area embraces some of the most beautiful and fertile country in the State. Much the greater part is prairie, not continuous but divided by gentle ridges, usually timbered, into smaller sections locally named as Osborne's Prairie in western Fountain County, Shawnee, Twelve Mile, Six Mile and Potato Creek prairies further east, and north of these Wea Plains and Wild Cat prairies.

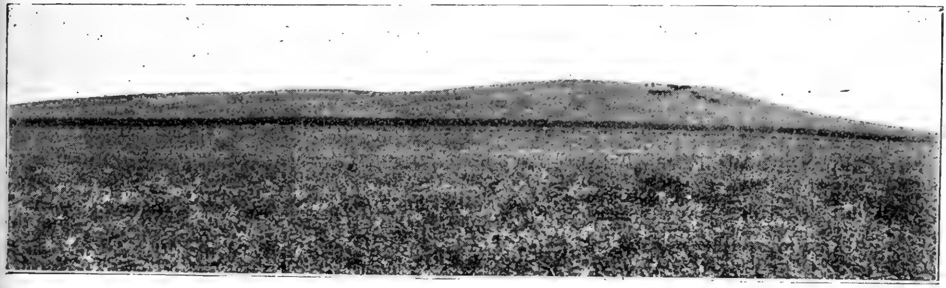
The main water-shed has a northward slope from northern Montgomery County to the Wabash, the main drainage line of the region. The slope rises rapidly to the east from the eastern side of the South Fork of Wild Cat Creek, and the country becomes distinctly a timbered region with clay soil. The southern divide is also a clay and naturally heavily timbered region, with a few narrow re-entrant strips of prairie. The country is diversified by several ridges and a great number of small gravel hills or mounds. The country to the north of the Wabash to a distance of from two to six miles from the river is a clay country, much of it still heavily timbered and very much broken by the knobs and basins characteristic of moraine topography. The country bordering the region on the south has this characteristic topography but of a more subdued type. Subordinate to these are several ridges, the relation of which to the others is not in every case clearly apparent. One of these extends almost due east from the town of West Point, Tippecanoe County, a distance of twelve miles, where it bends southeast and extends to the southeast corner of Tippecanoe County. From this angle there also extends a broken chain of mounds northeast to near Dayton. Another well defined ridge, from the low crest of which rise many mounds, extends southeast from near Independence, on the Wabash, to Darlington, Montgomery County. Parallel with it on its eastern slope lies the belt of bowlders well known to Indiana geologists. Shorter and less conspicuous ridges extend east and west, at distances of about three miles apart, across the part of Tippecanoe County further south. Two or three such ridges traverse the northern part of Fountain County. Many mounds dot the region in no discernible relation to each other or to the chains and ridges. All these ridges and mounds of gravel have the regular stratification of water-laid deposits.

The drainage of the region is interesting and peculiar. The Wabash crosses Tippecanoe County through an immense deposit of gravel extending from the eastern to the western boundary of the county, having a width of from one to six miles and from two to three hundred feet deep. Between Warren and Fountain counties, from the western side of Tippecanoe to Portland, Fountain County, the stream runs on bedrock in a valley about a mile wide and one to two hundred feet deep. The smaller streams of Tippecanoe County, south of the Wabash, converge from the eastern and southern more elevated clay plains and the line on the southwest formed by the Darlington-Independence ridge. West of this the streams run west into the Wabash. The unusual course of the Wea Creek and of Coal Creek should be noticed particularly, the course of the former, forming a great semicircle, the latter having a course with an abrupt bend in it strangely similar to that of the Wabash. It should be noted also that the streams just over the south and southwest divides of the Wea basin in several places have their sources very near those of this basin, and in all such places there is a sag or connecting valley across the divide. Notice, for examples, the heads of South Flint and North Shawnee, Little Wea and Big Shawnee, Big Wea and Coal creeks. Note also the nearness of the northward-flowing tributary of Shawnee to the elbow in Coal Creek.

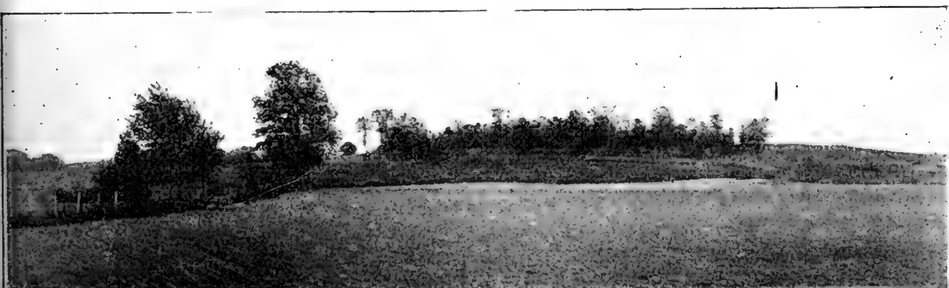
The foregoing statement of topographic facts is made in view of a possible solution of some problems that are suggested by them.

Mr. Chamberlain has called this a region of readjustment in glacial movement, and this statement seems to be the key to the solution of the problems that present themselves. When the last great North Ameri-

View of Part of Shawnee Prairie, Tippecanoe County, Indiana. (Bed of an Ancient Lake).



Shawnee Mound, South Slope, Tippecanoe County, Indiana.



Cook's Mound. Two Miles Southeast of New Richmond, Montgomery County, Indiana.

can ice sheet invaded Indiana it sent forward advance columns along the lines of low depression. Of these lines, the principal ones, a southward-moving lobe from the Lake Michigan depression, a southwestward-moving lobe from the Saginaw-Huron depression, and a west southwestward-moving lobe from the Erie depression, converged in northern Indiana, became confluent and moved southward to central Indiana. The climate then became warmer and the ice sheet began its retreat in an order the inverse of its advance. It melted away on the divides first and persisted much later in the lines of depression. Immense quantities of water from the melting ice, the accumulated precipitation of countless ages set free from its long bondage by the Frost King gathered in lakes in the depressions of the vacated regions, or swelled to immense size the streams that ran from the ice front. A new topography was imposed upon the region of glacial action. It is as a detail in the general scheme that the region described finds its explanation.

The converged lobes before mentioned moved down to the Shelbyville moraine extending from northern Vigo County northeast through Parke, east through Putnam and thence southeast. This moraine extends as a continuous plain, trenched by streams, bearing on its surface the weak dome-shaped swells that mark it as morainic in character to the northern part of Montgomery County, extending northwestward to and across the Wabash, which was one of its great terminal drainage lines, into which flowed Raccoon and Sugar creeks, mighty streams from the ice border further east. As the ice retreated to the present divide between Sugar and Coal creeks, the slope descending to the north was gradually uncovered, and a lake began to form along the southern border of the glacier, which overflowed south across the divide by Potato, Lye and Black creeks to Sugar Creek. Later, Coal Creek took its way west along the ice border and finding an outlet stream running south, or a southward bend in the ice front, it turned south at the elbow. This being lower than the outlets further east caused their abandonment, the water flowing through the sags in the Independence-Darlington Kame Moraine. This moraine is a weak frontal moraine of the Erie lobe and it was laid down in the lake and perhaps afterwards much dissected by wave action. The ice sheet halted for a long time at the West Point, or what is better known as the High Gap Ridge, the drainage then being by Flint Creek along its front across the divide to Shawnee, thence west into the Wabash, the terminal drainage stream of the Michigan lobe, the Wea-Coal Creek outlet being probably still maintained. The High Gap Ridge is thought to be a moraine of the Michigan lobe. Later the ice retreated to the great moraine north of the Wabash, which river then extended itself from the great bend northeast along the border of the Michigan lobe in its present course. The lake held in the Wea basin then formed an outlet stream to the north and Wea Creek and its tributaries came into existence, the main stream following the moraine on the east and north sides where the deepest part if the lake nad been. The retreat continuing, the region east of Lafayette as far as Dayton, held a lake which flowed out where the moraine running east from West Point bends to the southeast at a low sag locally known as Dismal Swamp. Later an outlet opened into the Wea at the west end of the lake, the bed of which is now known as Wild Cat Prairie. Later still an outlet was formed at the east end of this lake by the South Fork of Wild Cat Creek extending headward from its junction with Middle Fork along the western border of the Erie lobe.

The Michigan and Erie lobes were now becoming differentiated again. The heavy moraine north of the Wabash is a terminal moraine of the Michigan lobe, the rapidly rising till plain east of the junction of Wild Cat Creek is the main frontal moraine of the Erie lobe. Tippecanoe River in its lower course is a former outlet of an interlobate lake which existed for a long time before being finally drained westward by the retreat of the Michigan lobe. The great gravel deposit is probably the filling of a lake produced by the melting of a thick bed of ice which had filled a preglacial valley. The present Wabash Valley is the trench cut out by the sand-laden stream which for thousands of years carried the water from the still retreating Erie lobe.

Different layers of bowlder clay with beds of gravel interposed point to minor advances and retreats of the edge of the ice sheet over all the region.

The facts here set forth are derived from an intimate knowledge of much of the region and considerable field work in the portions not so familiar and the conclusions are set forth as a working hypothesis subject to revision upon the basis of further examinations. The hypothesis postulates the presence of the Michigan and Erie lobes in the region at the same time, which is a view not agreed upon by all who have studied the glacial phenomena of North America.

An Interesting Bowlder.

By Wm. A. McBeth.

On the lawn in front of the residence of Thomas B. Miller, one-half mile north of New Richmond, Montgomery County, Indiana, stands the very interesting bowlder, a cut of which is given herewith. It is nearly five feet in length, and from two to three feet in diameter. It is roughly cylindrical in shape, and so white as to give most people who see it the impression that it has recently received a copious coating of whitewash. A closer examination shows a curious and beautiful structure, which may be compared to that of an immense stick of white taffy, strands of which had been drawn out into small ropes, braided, twisted and then doubled or folded, given a final pull and allowed to cool.

A small fragment analyzed at the chemical laboratory of Rose Polytechnic Institute, Terre Haute, Indiana, by Mr. J. W. Shepherd, was pronounced foliated serpentine. It was found in excavating the cellar of the residence, in front of which it stands. A smaller bowlder of the same material, and no doubt a fragment of the larger one, was found near it in the excavation.

The location in on the ridge of the Darlington-Independence Kame Moraine and near the parallel bowlder train mentioned in the article on the Physical Geography of the Great Bend of the Wabash. Its presence, in the region where found, may be explained in the same way that the presence of the thousands of others may be explained, but its composition and structure mark it as so uncommon that its source would throw much light upon the direction and distance of movement of the drift in the region where it was found. It is hoped that this description may meet the eye of some person who can give information as to its probable source.

Bowlder of Foliated Serpentine, New Richmond, Indiana.

Headwaters of Salt Creek in Porter County.

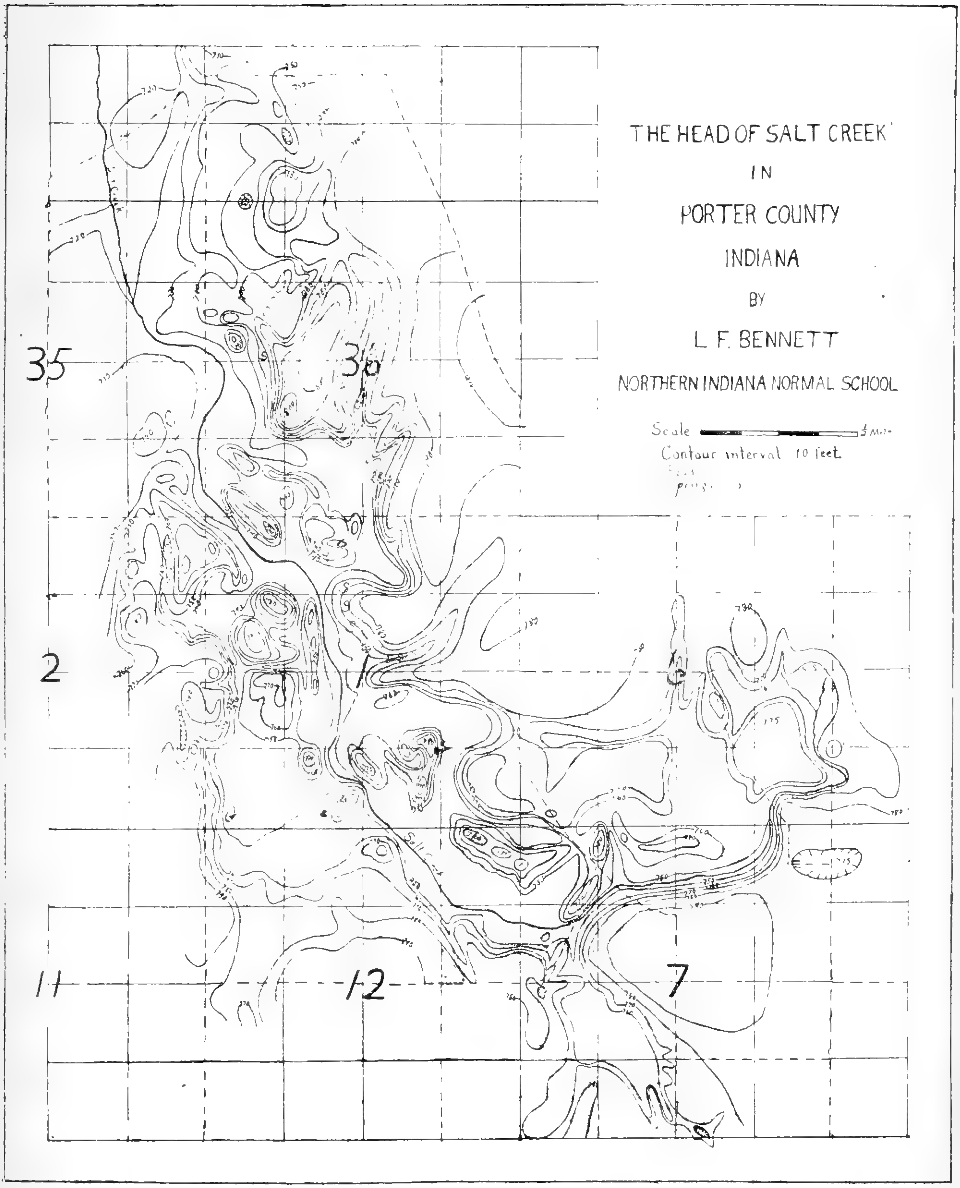
By L. F. Bennett.

Salt Creek rises three miles southeast of the city of Valparaiso, in section 6, 35 north, 5 west. It flows southwest one mile, thence in a north-northwesterly direction, cutting through the crest of the Valparaiso Moraine, and empties into the Calumet River in section 31, 37 north, 6 west. This paper has to do with the first four miles of its course.

Like many creeks in a drift region, it pursues a winding course through a marsh varying in width from one hundred yards to nearly a mile; and unlike most creeks it has several islands situated in its marshy bottom near its headwaters. These islands have their longer axes parallel with the general direction of the creek in that locality. They are from ten to fifty feet higher than the surrounding marsh and are from fifty yards to one-fourth of a mile in length. There are also tongues of land extending, in a few instances, one-fourth mile from the higher land and are connected with the higher land by low necks. The banks of the marsh, as a rule, are quite steep, and rise from forty to eighty feet above the creek bed. The marsh has so little slope that with the present price of land, it is not worth draining. It is so wet and uneven in most places that it is worthless for pasture. In the southwest quarter of section seven, there is a tributary marsh about ten feet above the level of the main marsh, and about forty acres in extent. It is connected to the larger marsh by a narrow channel. The sides of the marsh are from ten to twenty feet high and rather abrupt. During the greater part of the year there is no water in the connecting channel.

The flat marshy creek bottom, with its islands, tongues of land and abruptly sloping banks, furnishes a marked exception to the nearly level topography of the region to the south and east, which slopes very gradually to the Kankakee River.

The islands, and without doubt, many at one time were really such, are the most interesting features. Some are as high as the adjacent land on the sides of the marsh from which they appear to be cut; many have been eroded until they are but little above the general level of the marsh, and others have been nearly cut into two parts by unequal erosion They show every variety as to shape and height above the general level.


THE HEAD OF SALT CREEK
IN
PORTER COUNTY
INDIANA
BY
L. F. BENNETT
NORTHERN INDIANA NORMAL SCHOOL
Scale
Contour interval 10 feet.
35
36
2
11
12
7

The origin of the creek and its various features is a very interesting problem. It probably began as an original depression in the moraine, and, as at present, was fed by springs, the action of which is very apparent all along the creek's upper course. The head of the creek is formed by a number of small springs issuing from a low bank, and at various places many large perennial springs are found.

In section 2 (see map), on the east side of the creek, the springs have eaten back the bank until a terrace has been formed. This terrace is ten feet above the marsh, is from ten to seventy-five yards in width, is one-fourth of a mile long and in all places is composed of soft wet ground, showing that water is still issuing from beneath. From the terrace the land abruptly rises ten to twenty feet to nearly level ground.

If the tongues of land with their low necks are to be considered as islands nearly cut off and are to explain the origin of the islands, then there must have been a time when the quantity of water was much greater than at present. If there was more water most of it must have come from springs, as there is no evidence of water action except in the creek bed, the land on all sides being high and nearly level. Again, if the springs were more numerous and carried more water than at present, other evidence of their presence than that given above has entirely disappeared.

The narrow necks appear to have been cut out by the recessions of springs on opposite sides toward each other and which have dried up with changing climatic conditions.

There is no way at present to tell how deep the creek bed has been, as there are no wells of which sections may be obtained, except on the sides of the marsh and they are very shallow.

The accompanying contour map will give a good idea of the position of the islands and tongues of land with their relative heights. The contour interval is ten feet. The elevations were taken with an aneroid barometer and locations were made with a considerable degree of accuracy.

The Weathering and Erosion of North and South Slopes.

By Glenn Culbertson.

The experience of the writer in climbing the hills of southeastern Indiana, and especially those in the vicinity of Hanover and Madison, led to the opinion that, in certain valleys, there was a considerable variation in the inclination of the slopes.

During the last few months accurate measurements of the inclination of the slopes, of the depth and of the direction of trend, of four valleys or ravines were made with a view to ascertaining the amount of variation in the inclination of the slopes, and a reason for the variation where it was found.

The valleys or ravines, chosen for the measurements, are locally known as Butler, which is about one-half mile south of Hanover; Crowe, which borders the Hanover College campus on the south; Happy Valley, which borders the college campus on the north, and Clifty, which is located about two miles west of Madison.

The hills in the region of these valleys are capped with the so-called bluff limestone of the Niagara formation, the Clinton, and the Madison beds of the Ordovician. These rocks are comparatively uniform in texture and hardness throughout the region concerned. Butler, Crowe and Happy Valley ravines are less than a mile in length, and Clifty is but little more than two miles in length, from the mouth to the falls, which are found in each valley. The depth of these valleys, however, is approximatey 260 feet, aneroid measurement. The valleys are eroded to the level of the Ohio River, into which the streams occupying them empty.

The great depth of the ravines, as compared to their length, is accounted for by the fact that the Ohio-Wabash divide in this region approaches in places to within a mile and a half of the Ohio River.

The streams which have formed the valleys, across the lower portions of which the sections were made, are all small, and, with the exception of Clifty, are just able to transport the materials brought into them and do not erode the sides to any extent. Hence, we have in these valleys exceptional conditions for the study of the weathering and erosion of slopes.

Two sections were made across each valley with the exception of

Butler, and in each case the sections were intended to be fair averages of the slopes. The following data were obtained as an average result of the sections made in each valley.

BUTLER RAVINE.

Direction of trend, north, 70 degrees west.
Inclination of south slope (i. e., slope facing south), 25 degrees.
Inclination of north slope, 28 degrees.
Depth, approximately, 260 feet.

CROWE RAVINE.

Direction of trend, north, 80 degrees west.
Inclination of south slope, 22 degrees.
Inclination of north slope, 26½ degrees.
Depth, 260 feet.

HAPPY VALLEY RAVINE.

Direction of trend, north, 40 degrees west.
Inclination of southwest slope, 21 degrees.
Inclination of northeast slope, 26 degrees.
Depth, approximately, 255 feet.

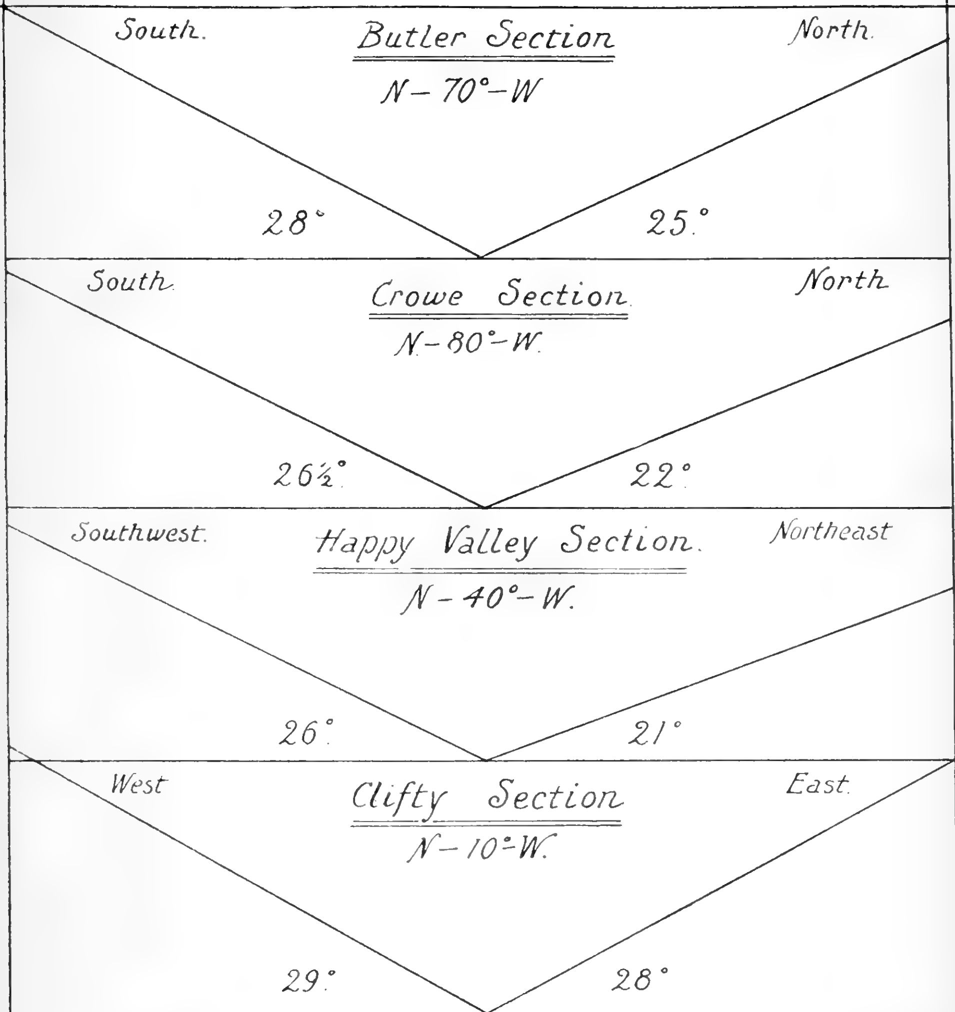
CLIFTY VALLEY.

Direction of trend, north, 10 degrees west.
Inclination of west slope, 28 degrees.
Inclination of east slope, 29 degrees.
Depth, approximately, 270 feet.

(Reference to the accompanying figures will aid much in appreciating the variations in the slopes.)

These cross sections indicate a decided variation in the rate of weathering on the two slopes, in the cases under consideration, where the direction of valley trend is from east and west to southeast and northwest approximately, but that there is little variation where the valley trends approximately north and south. Sections taken of other valleys extending in a general north and south direction verify the latter statement.

(40)



Cross sections of four valleys near Hanover, Ind., showing the inclination of the slopes.

The direction of the trend of each valley is placed below the name.

The cause of the more rapid weathering of south slopes (i. e., those facing the south) is, no doubt, partially due to expansion and contraction. The massive rocks of the Niagara, Clinton and Madison beds of the Ordovician have been more rapidly broken to pieces on the south slopes than on the north, because of the much greater daily change of temperature on the south than on the north slopes. This is especially true during the winter season.

The chief agent, however, in producing the variations in the sections noted, is that of frost. The action of frost in producing such variation is three fold. First, the almost daily thawing and freezing of the moisture in the rocks of the south slopes during the winter produces a more rapid disintegration of these rocks, than would take place on the north slopes, where thawing occurs but few times comparatively during the winter season.

Again the surface soil of the slopes facing the south goes through the freezing and thawing process several scores of times during the winter, while that of the north slopes remains frozen almost continuously during the average wintry season. The "creeping of soils," resulting from frost action, is too well known to need explanation here, and must, to a large degree, account for the variations noted.

Again, the soil of the north slopes is frequently frozen, and even covered with snow or ice, while that of the south slopes is unfrozen. Hence, the erosive action of many winter rains is almost nothing on the north slopes, while it may be quite marked on the south slopes. This is an additional cause for the variation noted in the sections taken.

With the exception of the north slope of Crowe Ravine and the east slope of Clifty, the region considered is all wooded, while the unwooded slopes have been so but for a few years. What the effect of weathering and erosive agencies may be upon north and south slopes of land from which the forest trees have long been removed, has not been investigated, but from the greater abundance of loose stones on the south slopes of cleared and more or less neglected land, it is probable that the variation in the effects of weathering and erosion on the north and south slopes is even more striking than in the case of land covered with forest growth.

A Cranium of Castoroides Found at Greenfield, Ind.

By Joseph Moore.

Castoroides has been correctly represented as decidedly the greatest rodent, recent or fossil. This Greenfield cranium, with the nasals and premaxillary restored, would measure a foot and an inch in length. Compare this with the heads of beavers and ground hogs, the largest rodents with which we are familiar. Even the great capybara of South America is quite dwarfed in the comparison.

The scarcity of Castoroides remains and the interest which for various reasons attaches to them make every considerable fragment of them worthy of mention. So far as relates to material for study, Indiana has furnished far more than any other State. On this point, and for further details, I refer the reader to a detailed report of the Randolph County skeleton in the Journal of the Cincinnati Society of Natural History for October, 1890, and also to the American Geologist, Vol. XII, August, 1893. In the latter, mere mention is made of the cranium now under consideration. At that time it was the property of Dr. M. M. Adams, of Greenfield.

To said Dr. Adams I am greatly indebted for the transfer of the same to the Earlham College museum.

Little is known of its history save that it was found, years since, by some one who was digging or grading in Greenfield or vicinity.

It is the cranium of a larger representative of the species than the Randolph find, as described in the American Geologist and in the Cincinnati Journal. Although the thin pterygoid blades are badly broken away, still that characteristic feature of the double posterior nares is clearly shown.. This is especially noteworthy as it pertains to no other known species, fossil or recent.

This giant beaver-like rodent occupied our marshes and streams of quaternary times in company with the mastodon and mammoth, and probably became extinct, largely through the agency of prehistoric man, somewhat as our modern beaver appears to be going to-day.

The two plates, with explanations, which accompany this paper, will give a better idea of the dimensions and also of a few anatomical details.

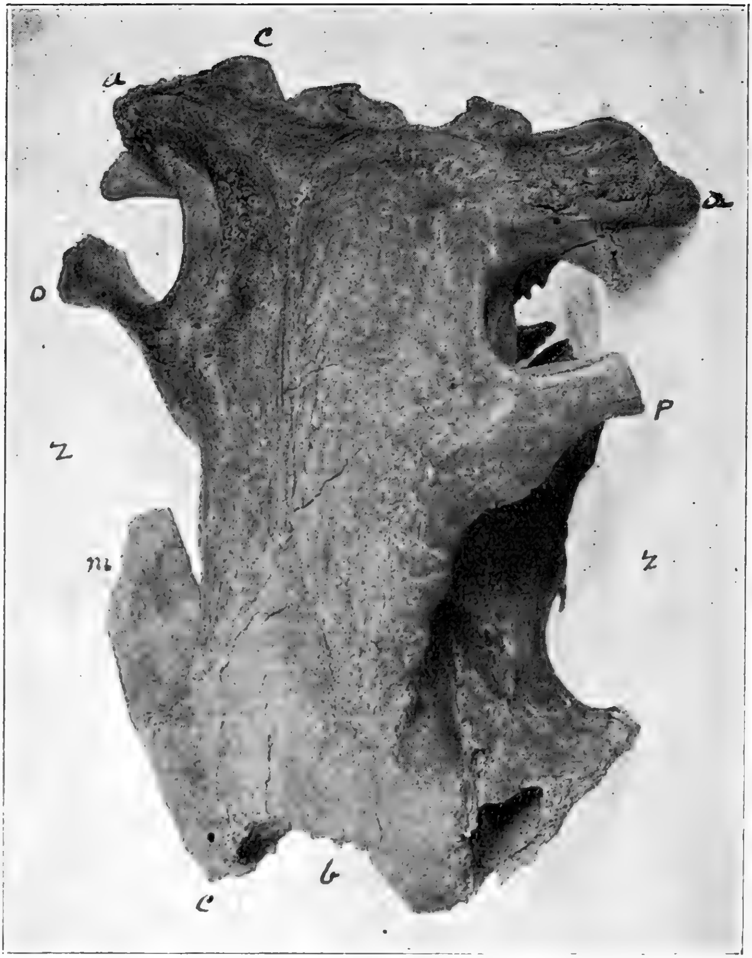


PLATE I.—FRONT AND UPPER VIEW.

From *c* to *c*, 9.25 inches.
From *a* to *a*, 7 inches.
From *o* to *p*, 7.6 inches.
From *z* to *z*, or from outer to outer of zygomatic arches, if restored, about 8.5 inches.
m.—Malar process to which anterior of zygoma was attached.
o.—Temporal process to which posterior of zygoma was attached.
b.—The border from which nasals were broken away.

PLATE II.—POSTERIOR VIEW—ALSO UNDER SURFACE, MUCH FORESHORTENED.

pp. Pterygoid fossæ, caused by an inward bending of two thin, blade-like processes, making a double partition, thus closing up the middle of the posterior nares dividing it into an upper and a lower.

s. A straw entering the upper posterior nares.

t. A straw inserted in lower posterior nares.

oo. Outer to outer margins of occipital condyles, distance 2.6 inches.

gg. The four upper grinders, right side. Length of the series, *g* to *g*, 3.9 inches.

mm. Width of palate posteriorly, 2 inches. Lateral diameter of foramen magnum, 1.2 inches.

On the Waldron Fauna at Tarr Hole, Indiana.

By Edgar R. Cumings.

Perhaps no locality is more famous for its fossils, or better known to collectors than Waldron, Indiana. There is another locality, however, which, though less well known, promises to afford almost as rich a field for collecting. I refer to Tarr Hole, in Bartholomew County, Indiana.

This locality, though mentioned by Foerste and others of the Indiana Geological Survey, has never hitherto afforded an extensive list of fossils. Two years ago the present writer visited the locality in company with a student of the department of geology of Indiana University, and made a collection from which the following species have been identified. The bed is excavated each spring by the high water, the fossils being spread out over a sand spit, making their collection very easy. (The species are listed in the order of identification.)

1. Eucalyptocrinus (roots) (c).
2. Trematopora osculum *Hall* (rr).
3. Saginella elegans *Hall* (rr).
4. Trematopora infrequens *Hall* (rr).
5. Spirifer bicostatus var. petilus *Hall* (rr).
6. Chætetes consimilis *Hall* (r).
7. Lichenalia concentrica *Hall* (c).
8. Trematopora subimbricata *Hall* (rr).
9. Eucalyptocrinus cælatus *Hall* (c).
10. Dalmanites verrucosus *Hall* (c).
11. Fenestella acmea *Hall* (rr).
12. Mytilarca sigilla *Hall* (rr).
13. Trematopora minuta *Hall* ? (rr).
14. Coelospira disparilis *Hall* (rr).
15. Spirifer radiatus *Sowerby* (rr).
16. Anastrophia internascens *Hall* (a).
17. Uncinulus stricklandi (*Sowerby*) *Hall and Clarke* (c).
18. Homœspira evax *Hall* (a).
19. Atrypa reticularis (*Linn.*) *Hall* (a)
20. Streptelasma radicans *Hall* (rr).
21. S. borealis *Nicholson* (rr).
22. Platystoma niagarense *Hall* (c).
23. Camarotœchia whitei *Hall* (aa).

24. Camarotœchia (?) neglecta *Hall* (a).
25. Camarotœchia (?) indianensis *Hall* (aa).
26. Camarotœchia (?) acinus *Hall* (r).
27. Meristina maria *Hall* (c).
28. Dalmanella elegantula *Hall* (c).
29. D. hybrida *Hall* (c).
30. Spirifer crispus (*Hisinger*) *Hall* (c).
31. ——— ——— var. simplex *Hall* (rr).
32. Leptæna rhomboidalis (*Wilckens*) *Hall and Clarke* (c).
33. Orthotetes subplanus (*Conrad*) *Hall and Clarke* (c).
34. Whitfieldella nitida *Hall* (a) (large form).
35. ——— ——— ——— ——— (small form) (a).
36. Rhynchotreta cuneata var. americana *Hall* (a).
37. Dictyonella reticulata *Hall* (c).
38. Nucleospira pisiformis *Hall* (c).
39. Calymine niagarense *Hall* (r).
40. Eucalyptocrinus crassus *Hall* (rr).
41. Trematopora varia *Hall* (r).
42. Favosites forbesi var. occidentalis *Hall* (r).
43. Cornulites proprius *Hall* (rr).
44. Paleschara maculata *Hall* (rr) (on Camarotœchia indianensis).
45. Meristina rectirostris *Hall* (r).
46. Homœspira sobrina (*Beecher and Clarke*) *H. and C.* (rr).
47. Strophostylus cyclostomus *Hall* (rr).
48. ——— ——— ——— var. disjunctus *Hall* (rr).
49. Astylospongia præmosa *Goldfuss* (rr).
50. Spirifer cf. niagarensis *Hall* (rr).
51. Stropheodonta sp.
52. Modiolopsis perlata ? *Hall* (rr).
53. Paleschara (?) sphærion *Hall* (rr).
54. Rhodocrinus (lyriocrinus) Melissa *Hall* (rr).
55. Orthotetes subplanus ? (specimen 3.5 mm. long).
56. Lichas boltoni var. occidentalis *Hall* (rr).
57. Chonetes nova-scotica *Hall* (rr).
58. Lamellibranch cf. pterinea sp.
59. Orthotetes tenuis *Hall* (rr).
60. Trematopora granulifera *Hall* (r).
61. Leperditia faba *Hall* (rr).

62. Homalonotus armatus *Hall* (rr).
63. Ceramopora labecula *Hall* (rr).
64. Stropheodonta profunda *Hall* (fragment).
65. Pholidops ovalis *Hall* (interior of ventral valve).
66. Fenistella parvulipora *Hall* (rr).
67. Strophiodonta striata *Hall* (rr).
68. Trematopora echinata *Hall* (rr).
69. Stephanocrinus (fragment).
70. Fistulipora maculata (*Hall*) (r).
71. Crania sp. (rr).

(The relative abundance of species in the above list is indicated by the letters in parentheses, aa indicating very abundant; a, abundant; c, common; r, rare, and rr, very rare.)

In the species Whitfieldella nitida no transitional forms were found between the large and small varieties, though a considerable number of specimens of both varieties were obtained.

The form given by Hall as Lichenalia concentrica var. maculata is here referred to the genus Fistulipora, since all the specimens from the present locality in which the maculæ are present, also possess mesopore apertures in the interapertural spaces, a character not possessed by Lichenalia as defined by Simpson. (See 14th Ann. Rept. State Geologist of N. Y., p. 559.)

The Stream Gradients of the Lower Mohawk Valley.

By Edgar R. Cumings.

During a recent study of the area mapped as the Amsterdam (N. Y.) sheet of the U. S. Geological Survey* the writer was struck by certain peculiarities of the streams of this area emptying into the Mohawk River.

As will be seen by a reference to the accompanying map, practically all of these streams have a relatively flat gradient throughout their upper courses. The streams A, D and F have not cut through the glacial till that forms the beds of their lower courses, while all the streams A, D, E, F, G, H, flow over rock beds in their upper courses.

*The results of this study dealing with the stratigraphy and paleontology of the Lower Silurian formation will be published as a part of Bulletin No. 32 of the New York State Museum.


N
E
W
S
FAULT LINE
AMSTERDAM
CRANES VILLAGE
HOFFMANS FERRY
240 AT.
X
Y
Ca. = Calciferous sandrock
T. = Trenton limestone
U. = Utica shale
Hd. = Hudson "
Dr. = Drift.

In all cases the upper courses are more mature, both as regards slope of the bed and with regard to steepness of banks and presence of waterfalls, etc.

The profiles to the right of the map are accurately drawn to scale from the data of the U. S. Topographic sheet. It will be seen that there is a remarkable uniformity in one particular, namely, the points (M, N) where the prolongations of the upper slopes intersect. A line coinciding with xy, the upper slopes of A and D, meets the prolongation of a line coinciding with EE′; the upper course of E, at M, and a line coinciding with the upper course of F (FN) meets the line coinciding with the upper courses of G and H (GG′, HH′) at N (nearly).

This state of affairs is not due to structure, for, as will be seen by the geologic sections (XY and W V), the formations and structure encountered by the several streams vary to a marked degree. G and H flow over hard, arenaceous limestone (Calciferous and Trenton in part)); F flows over the soft Utica shale; A flows over the even more yielding Hudson shales, and D and E over Utica. A and F are determined by a fault line. The lower courses, where not in glacial drift (F, D and A), are in limestone (G and H) and Utica shale (E).

There are three possible explanations of the peculiarity in question. (1) These mature upper gradients represent a period of base-leveling and subsequent elevation which has rejuvenated the streams, allowing them to re-excavate their beds; (2) the Mohawk Valley was plowed out to a depth of 240 to 260 feet by the Mohawk Valley glacier*; (3) the water of the Mohawk was dammed back to a level of 240 to 260 feet above the present river level for a length of time sufficient for the streams in question to mature.

Of these possible explanations the first is the more probable inasmuch as the stream, E, is manifestly preglacial and has been modified in its upper course to some extent by drift, nevertheless the upper gradient of this stream conforms distinctly to a river at a level of 500 feet (A. T.), instead of at a level of 240 feet as in the present Mohawk River. We must, therefore, believe that this stream reached grade before it was interfered with by the presence of the glacier.

As for the hypothesis of a plowing out of the Mohawk Valley, this seems hardly probable in view of the fact that the Hoffmans Ferry fault

*See Dana, A. J. S. (2) Vol. 35, pp. 243–249; Brigham, Bull. Geol. Soc. Amer., Vol. 9, pp. 183–210; Chamberlain, U. S. G. S. Third Ann. Rep., pp. 360–365.

offers a substantial barrier of hard limestone to such an amount of erosion on the part of the glacier. Furthermore, the gradients of the lower courses of some of the streams, at least, such as A, F and D, where the streams are still flowing through till must have been formed prior to the presence of the glacier since they are partly plugged with glacial debris. It seems likely, then, on the whole, that these streams had cut to grade not long prior to the glacial epoch and were rejuvenated together with the entire Mohawk system by the elevation which preceded or accompanied the glacial epoch.

Skull of Fossil Bison.

By W. G. Middleton and Joseph Moore.

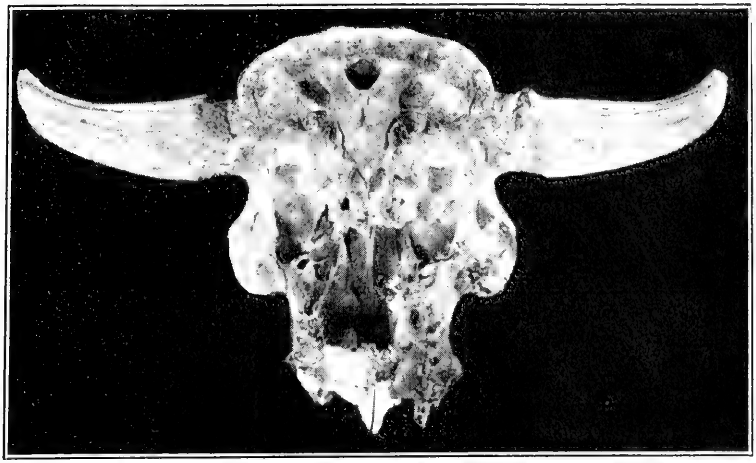
Let it be said here, by way of introduction, that Mr. Middleton, of the Vincennes High School, as some members of the Academy will remember, obtained and reported to the late meeting the above-named specimen, reporting it as probably Bison latifrons, Leidy. Mr. Middleton gave his report verbally to the Academy, and has recently been in poor health, so that he has not been able to give it further study and write it up for publication. He, therefore, requests me (J. M.), since the specimen has been sent to Earlham College, to forward measurements, photographs and whatever notes may seem proper.

This cranium was found in 1896, a few miles from the city of Vincennes, Indiana, by a Mr. Brower. It was some six feet below the surface, partly unearthed by the caving in of the bank of a deep ditch.

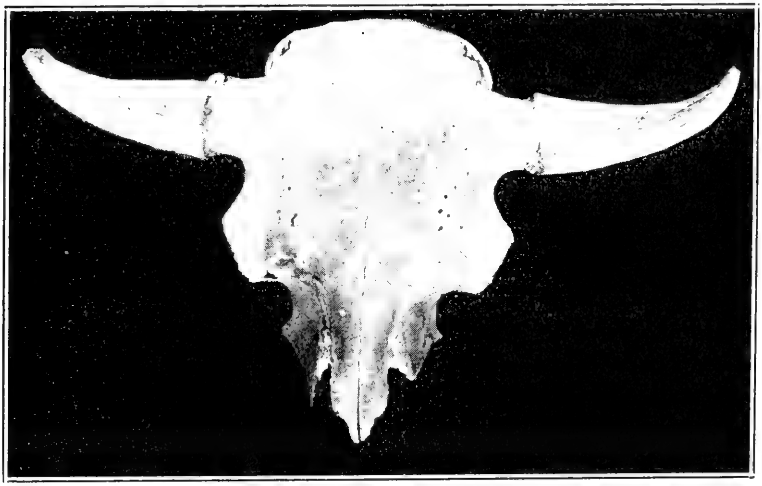
It will be noted that what appears to be the horns are but the horn cores—processes of the frontal bones for the support of horns long since decayed. The horns, if restored, would add, say a foot to each projection.

	Ft.	*In.*
Distance from tip to tip of horn cores, direct line	3	0 *
Circumference of horn cores near base	1	0
From tip to tip of horn cores, line of outer curves	3	9
Width of forehead between horns	1	3
Greatest width from outer to outer of orbit borders	1	2½
Least width of forehead (between eyes and horns)	1	½
Length of face from occipital crest to anterior of nasals	1	9

* This measurement supposes an inch, more or less, to be restored to the tip of the right horn core, which has been broken off. Measurement as it appears in the cut is 35 inches.



Basal and Occipital View.



Front View.

Posterior View.

(It will be noted that the premaxillaries and a portion of the maxillaries are wanting With these restored the face would be six to eight inches longer.)

	Ft.	In.
Greatest width of occiput, right and left................	1	½
Greatest width of occipital condyles, right and left......	0	5½

The horn cores at base are warty and spurred; throughout their length they are ridged and grooved.

A cross section of these cores at almost any point would give, approximately, a circle having an irregularly notched border.

The face is slightly depressed between the eyes, but the forehead above the eyes is moderately convex, both vertically and crosswise. This latter feature is the more marked immediately below the occipital crest.

The cranial cavity is perfect; so are the zygomatic arches. The maxillaries, as will be seen from photograph No. 2, are quite defective. The left maxillary has two fragmental grinders, second and third, numbering from behind.

We have called this a Fossil Bison, but the fact that it was found several feet below the surface does not, of itself, prove it to represent a species different from the ordinary recent (though almost extinct) "buffalo"—Bison bison. Remains of our recent bison have many times been found in peat, loam, loess and in ordinary marsh ground.

This specimen from Vincennes bears a close resemblance to the modern buffalo in many details, and yet it is evidently specifically different.

Prof. F. A. Lucas, of the U. S. National Museum, in his Memoir on the Fossil Bison of North America, describes the following six species—B. occidentalis, B. antiquus, B. crassicornis, B. alleni, B. ferox, and B. latifrons. This Vincennes specimen is *not* B. latifrons, as we suggested at the meeting of the Academy, as is clearly ascertained from further study and comparison.

From the size (and this is evidently a well-matured skull), from the length, diameter, direction, curvature and taper of the horn cores, we announce it, somewhat cautiously, as B. antiquus Leidy. In all of the above named particulars, and others we might name, it agrees much more nearly with said species than with our living bison.

Remains of B. antiquus have heretofore been found in two localities in California and at Big Bone Lick in Kentucky.

Fragments of fossil bison and allied forms have for a century, more or less, been called in a general way remains of a great American ox.

The accompanying plates, with the measurements, will aid the reader as to the size and form of the cranium we are studying. We are indebted to Prof. R. W. Barrett for photographs, also to Dr. J. Lindahl, of Cincinnati, for photographs of B. latifrons for comparison.

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