TRANSACTIONS

OF

THE ACADEMY OF SCIENCE OF ST. LOUIS.

VOL. XIII.

JANUARY 1903 TO DECEMBER 1903.

PUBLISHED UNDER DIRECTION OF THE COUNCIL.

ST. LOUIS:
NIXON-JONES PRINTING CO.

CONTENTS.

CORRECTIONS.*

P. 7, line 5. — For lumen is, read lumina are.
P. 9, line 18. — For oval, read oral.
P. 12, line 32. — For Fig. 5, read Figs. 8, 10 and 11.
P. 14, line 20. — For Plate II. fig. 2, 3, 5, read Plate II. fig. 3.
P. 34, line 28. — For Maccoy, read M'Coy.
P. 47, line 22. — For Codastus, read Codaster.
footnote. — For ralated, read related.
P. 49, line 10. — For impossibie, read impossible.
P. 51, lines 13, 15. — For Canedayi, read Cassedayi.
P. 53, line 22. — For ambulacria, read ambulacra.
P. 55, line 18. — For plicable, read plicated.
line 35. — For prominent, read promising.
P. 59, line 18. — Omit comma.
Explanation of Plate II. No. 5. — Add, enlarged four times.
No. 11. — Add, in a Codaster.
Explanation of Plate IV. No. 6. — For pyramidalis, read bipyramidalis.
P. 69, line 18. — The equation should read $S = a + b\epsilon^{-kt}$.
P. 72, line 5. — For 13.5, read 19.95.
P. 147, equation (12). — For $(2 - n)$, read $(2 - n)^2$.
P. 155, line 3. — For $2C$, read $2C_P$.
last line. — For aT, read dT.
P. 156, equation (17)′. — For M —, read $M =$.
P. 157. — For $W = 4\pi\int^{\infty} R^2 Pd R$, read $W = 4\pi\int_R^{\infty} R^2 PdR$.
P. 160, equation (41) and preceding equation. — For C_p, read C_P.
P. 163, equation (50). — Read, $S = \frac{(8 - 5n)(4 - 3n)}{3(2 - n)^2(5k - 3)} \frac{C}{J}$.
following equation. — Read $= 0.177 \frac{C}{J}$.
P. 181, line 21. — For Hall, read Hale.

* Some of these changes require to be made in only the latter part of the edition, from which type appears to have fallen.

MEMBERS.

1. PATRONS.

Eliot, Henry W........................2635 Locust st.
Harrison, Edwin...... ....3747 Westminster pl.
McMillan, Mrs. Eliza.............. ..25 Portland pl.
McMillan, William Northrop.......25 Portland pl.

2. ACTIVE MEMBERS.

Adkins, James...........................Park and Vandeventer avs.
Alleman, Gellert*.....................Swarthmore College,
Swarthmore, Pa.
Allen, Terry W......... ....5061 Lindell av.
Alt, Adolf......................... .....3036 Locust st.
Andrews, William Edward*........Taylorville, Ill.

Bain, Robert Edward Mather......900 Locust st.
Bailey, Liberty Hyde*......... .....Ithaca, N. Y.
Baker, Carl Fuller*...................Pomona College, Claremont, Calif.
Barck, Carl ....2715 Locust st.
Bartlett, George M....................215 Pine st.
Baumgarten, Gustav...................4900 Berlin av.
Bean, Tarleton Hoffman*... ....Administration bldg.,
World's Fair.
Becktold, William B..... ....212 Pine st.
Bernays, A. C...........................3623 Laclede av.
Bixby, William Keeney ....13 Portland pl.
Boeckeler, William L.................4441 Laclede av.
Bolton, Benjamin Meade............4160 McPherson av.
Brannon, Melvin A.*....... ....University, N. Dak.
Brennan, Martin S.....................1414 O'Fallon st.
Brimmer, George G..... ....6900 Michigan av.
Brookings, Robert S...................5125 Lindell av.
Brown, Daniel S.......................2212 DeKalb st.
Brown, Willi.............................3526 Pine st.
Budgett, Sidney Payne...... ....1806 Locust st.
Burg, William.. ....1756 Missouri av.

---

* Non-resident.

Burnett, E. C.......... ....University Club.
Busch, Adolphus......................1 Busch pl.
Busch, Aug. A........................Busch pl.
Bush, Benjamin Franklin*.........Courtney, Mo.

Calvert, Sidney*......................State University, Columbia, Mo.
Carpenter, George O................Russell and Compton avs.
Carter, Howard*......................Webster Groves, Mo.
Carver, George Washington*......Tuskegee, Ala.
Chaplin, Winfield S....................3636 West Pine boul.
Chappell, W. G........................3810 Westminster pl.
Chase, E. C....... ....Oriel bldg.
Chauvenet, Louis.....................5501 Chamberlain av.
Chouteau, Pierre......................912 Security bldg.
Chouteau, Mrs. Pierre...............912 Security bldg.
Compton, P. C......... ....4156 Washington boul.
Comstock, T. Griswold....... .....3401 Washington av.
Conklin, Harry R.*....................Joplin, Mo.
Cramer, Gustav.........................c/o G. Cramer Dry Plate Co.
Crandall, George C....... ....4287 Olive st.
Crunden, Frederick Morgan.......Public Library.
Curtis, William S......................St. Louis Law School.
Cushman, Allerton S.*..............Bryn Mawr, Pa.

Dame, James E........ ....2353 Albion pl.
Dameron, Edward Caswell.*........Clarksville, Mo.
Davis, N. H.............................56 Vandeventer pl.
Davis, John D. ....421 Olive st.
De Menil, Alexander N.............De Menil bldg., 7th and Pine sts.
Diehm, Ferdinand.....................1834 Kennett pl.
Dodd, Samuel M.......................415 Locust st.
Douglas, Archer W...................c/o Simmons Hardware Co.
Drake, George S.......................64 Vandeventer pl.
Drosten, F. W. ....2011 Park av.
Duenckel, Frederick William......2912 Ellendale av.
Duggar, B. M.*.........................202 Hitt st., Columbia, Mo.

Eggert, Henry* ....1001 Collinsville av.,
E. St. Louis, Ill.
Eimbeck, August F.*................New Haven, Mo.
Eliot, Edward C.......................5468 Maple av.
Engler, Edmund Arthur*...........11 Boynton st., Worcester, Mass.
Erker, Adolph P............. ....608 Olive st.

Espenschied, Charles..................3500 Washington av.
Euston, Alexander....................3730 Lindell boul.
Evers, Edward........................1861 N. Market st.
Ewing, Arthur E......................6024 West Cabanne pl.
Eycleshymer, A. E...................3650 Washington av.

Favor, Ernest Howard*.............Box 842, Columbia, Mo.
Fernald, Robert Heywood...........Washington University.
Fischel, Washington E..............3841 Washington av.
Forbes, Stephen A.*..................Urbana. Ill.
Fordyce, John R.*....................2223 Louisiana st., Little Rock, Ark.
Forster, Marquard.....................2317 S. 13th st.
Francis, David R.....................4421 Maryland av.
French, George Hazen*.............Carbondale, Ill.
Frerichs, Frederick W...............4608 S. Broadway.
Frick, John Henry*...................Warrenton, Mo.
Fruth, Otto J..........................3066 Hawthorne boul.
Fry, Frank R..........................3133 Pine st.
Funkhouser, Robert Monroe.......3534 Olive st.

Gazzam, James Breading...........514 Security bldg.
Gecks, Frank...........................3453 Magnolia av.
Gerling, H. J...........................4320 Cook av.
Glasgow, Frank A......................3894 Washington boul.
Glasgow, William C...................2847 Washington av.
Goetz, Victor...........................129 Market st.
Goldstein, Max A......................3858 Westminster pl.
Goodman, Charles H..................3329 Washington av.
Graham, Benjamin B..................5145 Lindell boul.
Graves, William W....................1943 N. 11th st.
Graves, Willis Nelson................2813 Lafayette av.
Gray, Melvin L.........................3756 Lindell boul.
Greeley, Arthur W.....................Washington University.
Green, John.............................2670 Washington av.
Gregory, Elisha Hall..................3525 Lucas av.
Gregory, Elisha H., Jr.*.............Medical Dept., Univ. of Pa., Philadelphia.
Grindon, Joseph.......................3894 Washington av.
Gundelach, Chas. H...................3900 Westminster pl.
Gundelach, W. J.......................3703 Finney av.
Gurney, James.........................Tower Grove and Magnolia avs.
Guy, William Evans...................4380 Westminster pl.

Haarstick, Henry C....................Third and Chestnut sts.
Hambach, Gustav†....................1319 Lami st.
Hardaway, W. A......................2922 Locust st.
Harris, James Arthur................Washington University.
Hartmann, Rudolph...................2020 Victor st.
Held, George A......................International Bank.
Herzog, William.....................3644 Botanical av.
Hirschberg, Francis D...............3818 Lindell boul.
Hitchcock, Albert Spear*...........U. S. Dept. Agriculture, Washington, D. C.
Hitchcock, George C.................3877 Washington av.
Holman, M. L........................3744 Finney av.
Holmes, Joseph A.................... Mines Dept., La. Purch. Exposition.
Homan, George.......................323 Odd Fellows' bldg.
Hough, Warwick......................Circuit Court, Room 1.
Hughes, Charles Hamilton............3860 West Pine boul.
Huiskamp, John E.................... 5554 Cabanne av.
Hume, H. Harold*....................Lake City, Fla.
Hunicke, Henry August...............3532 Victor st.
Hurter, Julius......................2346 S. 10th st.
Hyatt, Robert J.....................U. S. Weather Bureau.

Irish, Henry C......................Mo. Botanical Garden.
Ives, Halsey Cooley.................Museum of Fine Arts.

Johnson, Reno De O.*................Desloge, Mo.
Jones, Breckinridge.................4010 Lindell boul.

Kall, Richard.......................1370 Goodfellow av.
Keiser, Edward H....................Washington University.
Keyes, Charles R.*..................State School of Mines, Socorro, New Mex.
Kinealy, John H.*..................1108 Pemberton bldg., Boston, Mass.
King, Goodman.......................78 Vandeventer pl.
Kirchner, Walter C. G...............1211 N. Grand av.
Klem, Mary J........................1808½ Lafayette av.
Kodis, Theodore*....................Schadow, Kowno, Russia.
Krall, George Warren................Manual Training School.

Lackland, Rufus J...................1623 Locust st.
Langsdorf, Alexander S..............Washington University.

† Elected a life-member January 3, 1882.

Leavitt, Sherman....................Washington University.
Lefevre, George*....................State University, Columbia, Mo.
Leighton, George Bridge............803 Garrison av.
Letterman, George W.*.............Allenton, Mo.
Lichter, John J..........................1740 Simpson av.
Lloyd, Hiram..............................Odd Fellows' bldg.
Loeb, Hanau Wolf....................3559 Olive st.
Ludwig, Charles V. F................1509 Chouteau av.
Luedeking, Robert.....................1837 Lafayette av.
Lumelius, J. George..................1225 St. Ange av.
Lyon, Hartwell Nelles...............3910 Russell av.

Mack, Charles Jacob.................113 N. Broadway.
Mallinckrodt, Edward ....26 Vandeventer pl.
Mallinckrodt, Edward, Jr...........26 Vandeventer pl.
Markham, George Dickson.........4961 Berlin av.
Marx, Christian William*...........University of Cincinnati, Cincinnati, O.
Mason, Silas C.*........................Berea, Ky.
Matthews, Leonard....................300 N. 4th st.
McGee, W J ....World's Fair.
Meier, Theodore G....................3938 Washington boul.
Merrell, Albert.......................... 3814 Washington boul.
Meyer, John F............................1739 Pennsylvania av.
Michel, Eugene H......................2721 S. King's Highway.
Miller, Charles F........................1751 Missouri av.
Monell, Joseph T.*....................Flat River, Mo.
Monroe, Lee Ernest*.................Eureka, Mo.
Moore, Robert............................61 Vandeventer pl.
Mudd, Harvey G........................2604 Locust st.
Mueller, Ambrose*....................Webster Groves, Mo.

Nagel, Charles............................3969 Washington boul.
Nasse, Aug.................................209 N. 2d st.
Nautze, Gustav...........................2868 S. 18th st.
Nelson, Aven*............................Laramie, Wyom.
Niedringhaus, George W............3745 Lindell boul.
Nipher, Francis E......................Washington University.
Norton, J. B. S.*........................College Park, Md.

Oglevee, Christopher Stoner*......Lincoln, Ill.
Olshausen, Ernest P...................1115 Rutger st.
Olshausen, George R.*...............Cornell University, Ithaca, N. Y.

O'Reilly, Andrew J....................1507 Papin st.
O'Reilly, Robert J....................3411 Pine st.
Outten, W. B..........................Missouri Pacific Hospital.
Overstolz, Herman....................100 N. Broadway.

Palmer, Ernest Jesse*...............321 S. Allen st., Webb City, Mo.
Pammel, Louis Hermann*.. ....Ames, Ia.
Pantaleoni, Guido.....................415 Locust st.
Parker, George Ward................417 Pine st.
Parsons, Charles......................2804 Pine st.
Pauls, Gustavus........................St. Louis Altenheim.
Pettus, W. H. H.......................4373 Westminster pl.
Pfeiffer, Egmont........................3921a Shenandoah av.
Pike, Sherman B..................... 5881 Cates av.
Pitzman, Julius.........................1900 S. Compton av.
Poats, Thomas Grayson*............Clemson College, S. C.
Post, Martin Hayward......... .....5371 Waterman av.
Preetorius, Emil.......................c/o Westliche Post.
Prewitt, Theodore F..................4917 Berlin av.
Prynne, Charles Martyn.............Lincoln Trust bldg.
Pulsifer, William H*..................Nonquitt, Mass.

Quaintance, A. L.*....................U. S. Department of Agriculture,
Washington, D. C.

Randall, John E............... ...... 1910 Olive st.
Raphael, Abraham....................5164 Raymond av.
Ravold, Amand.........................2806 Morgan st.
Reverchon, Julien* .... R. F. D. 8, Dallas, Texas.
Richter, Phil. George.................2424 S. 18th st.
Rieloff, F. C.................... ....3837 W. Pine boul.
Rilliet, Chas. E.........................4719 S. 9th st.
Robert, Edward Scott................1105 Missouri Trust bldg.
Robertson, Charles*..................Carlinville, Ill.
Roever, William Henry*.............Cambridge, Mass.
Rogers, Herbert F.....................c/o Provident Chemical Works.
Rolfs, Peter H.*.......... ....Tropical Laboratory, Miami, Fla.
Rosenwald, Lucian*....... ....Las Vegas, New Mex.
Ruf, Frank A.................. .... 5863 Cabanne av.
Runge, Edward C ....Vanol bldg.
Russell, Colton*........................325 S. Bunker Hill av.,
Los Angeles, Cal.
Ryan, Frank K..........................2725 Lawton av.

Sander, Enno..........................2807 Lawton av.
Sargent, Charles Sprague*..........Jamaica Plain, Mass.
Schmalz, Leopold.......................2824 Shenandoah av.
Schneck, Jacob*.......................Mt. Carmel, Ill.
Von Schrenk, Hermann.............Mo. Botanical Garden.
Schroers, John.........................1730 Missouri av.
Schrowang, Otto.......................Gay bldg.
Schwab, Sidney I......................2602 Locust st.
Schwarz, Frank.........................1520 Lafayette av.
Schwarz, Henry.........................1723 Chouteau av.
Schweitzer, Paul*......................Columbia, Mo.
Scott, Henry C..........................64 Vandeventer pl.
See, Thomas Jefferson Jackson*..Naval Observatory,
Mare Island, Cal.
Selby, Augustine Dawson*.........Wooster, O.
Senseney, E. M.........................2829 Washington av.
Sheldon, Walter L.....................4065 Delmar av.
Shepley, John F........................60 Vandeventer pl.
Shoemaker, William Alfred.........4386 Westminster pl.
Simmons, E. C..........................9th and Spruce sts.
Simmons, Wallace D.................9th and Spruce sts.
Sluder, Greenfield.....................2647 Washington av.
Smith, Arthur George*..............422 N. Dubuque st., Iowa City, Ia.
Smith, D. S. H..........................3646 Washington boul.
Smith, Irwin Z..........................87 Vandeventer pl.
Smith, Jared G.*.......................Honolulu, Hawaiian Islands.
Soldan, F. Louis.......................3634 Flad av.
Spiegelhalter, Joseph................2166 Lafayette av.
Starkloff, H. M.........................3623 Cleveland av.
Starr, John E.*..........................258 Broadway, New York City.
Staudinger, B............................3556 Lindell boul.
Stedman, John Moore*..............State University, Columbia, Mo.
Stevens, Charles D....................1749 S. Grand av.
Stevens, Wyandotte James.........4043 Juniata st.
Stocker, George J......................2833 S. King's Highway.
Strauss, Julius C.......................3516 Franklin av.
Stuart, James Lyall....................5346 Maple av.
Summa, Hugo...........................2249 St. Louis av.

Taussig, Albert E......................2647 Washington av.
Taussig, William........................3447 Lafayette av.
Teichmann, William C...............1141 Market st.
Terry, Robert James...................4105 Washington av.

Thacher, Arthur........................4304 Washington boul.
Thom, Charles*........................239 Hazel st., Ithaca, N. Y.
Thomas, John R......................420 N. 4th st.
Thomson, William H., Jr............3805 Lindell boul.
Thurman, John S......................416 Lincoln Trust bldg.
Timmerman, Arthur H..............2633 Park av.
Tittmann, Harold H..................3726 Washington boul.
Trelease, William ....Mo. Botanical Garden.
Tyler, Elza Edward*..................State University, Columbia, Mo.
Tyrrell, Warren Ayres...............3620a Folsom av.

Updegraff, Milton*....................12 Goldsborough Row,
Annapolis, Md.

Vallé, Jules F...........................3303 Washington av.
Van Ornum, John Lane.............Washington University.
Vickroy, Wilhelm Rees...............2901 Rauschenbach av.
von Schrader, George F............Wainwright bldg.
von Schrader, Otto U.................3749 Westminster pl.

Warren, William Homer.............1806 Locust st.
Watts, Millard F......................4362 Morgan st.
Weller, Stuart*.........................University of Chicago,
Chicago, Ill.
Westgate, John Minton*............Dept. of Agriculture,
Washington, D. C.
Wheeler, H. A...........................3124 Locust st.
Whelpley, Henry Milton.............2342 Albion pl.
Whitaker, Edwards...................300 N. 4th st.
Whitten, John Charles*..........Columbia, Mo.
Widmann, Otto ....5105 Morgan st.
Wilson, Edward Allen..............3745 W. Pine st.
Winkelmeyer, Christopher. ....3540 Lawton av.
Wislizenus, Frederick A ....3628 Cleveland av.
Witt, Thomas D.*......................Rushville, Ill.
Woodward, Calvin Milton...........Washington University.

Zahorsky, John.......................1460 S. Grand av.
Zawodny, Joseph*....................Schloss Lobes, Mscheno, bei
Melnik, Bohemia, Austria.

CONSTITUTION.

ARTICLE I. NAME.

Section 1. This Association shall be called "The Academy of Science of St. Louis."

ARTICLE II. OBJECT.

Section 1. It shall have for its object the promotion of science.

Sec. 2. As means to this end the Academy shall hold meetings for the consideration and discussion of scientific subjects; shall take measures to procure original papers upon such subjects; and shall, as often as may be practicable, publish its transactions. It shall also establish and maintain a cabinet of objects illustrative of the several departments of science, and a library of works relating to the same. It shall also place itself in communication with other scientific institutions.

ARTICLE III. MEMBERS.

Section 1. The Academy shall consist of *Active Members*, *Corresponding Members*, *Honorary Members*, and *Patrons*.

Sec. 2. *Active Members* shall be persons interested in science, and they alone shall conduct the affairs of the Academy.

Sec. 3. Persons not living in the City or County of St. Louis who may be disposed to further the object of the Academy by original researches, contributions of specimens, or otherwise, may be elected *Corresponding Members*.

Sec. 4. Persons not living in the City or County of St.

Louis may be elected *Honorary Members* by virtue of their attainments in science.

Sec. 5. Any person conveying to the Academy the sum of one thousand dollars ($1,000), or its equivalent, may be elected a *Patron*.

Sec. 6. Persons may be admitted to any of the preceding classes of membership, or dismissed therefrom, in accordance with the regulations prescribed by the By-Laws.

ARTICLE IV. OFFICERS.

Section 1. The officers of the Academy shall be chosen from the active members, and they shall consist of a

President,
1st Vice-President,
2d Vice-President,
Recording Secretary,
Corresponding Secretary,
Treasurer,
Librarian,
Three Curators,
Two Directors.

Said officers shall be elected at the time and in the manner prescribed by the By-Laws, and shall hold their offices for one year, or until their successors are elected.

Sec. 2. The duties of these officers shall be such as are customary and as prescribed by the By-Laws.

ARTICLE V. COUNCIL.

Section 1. The President, the two Vice-Presidents, the Recording Secretary, the Treasurer, the Librarian, and the two Directors shall constitute the Council of the Academy.

Sec. 2. The duties of the Council shall be to consider all plans conducive to the welfare of the Academy; to audit all bills and order payment of such as they may approve;

to consider all applications for membership; and to administer the business of the Academy, subject to the Constitution and By-Laws and to such instructions as may be given by the Academy.

ARTICLE VI. MEETINGS.

SECTION 1. The meetings of the Academy shall be held at such times and places as the By-Laws may direct.

ARTICLE VII. AMENDMENTS.

SECTION 1. Amendments to this Constitution shall be submitted in writing at a regular meeting. They shall be open to discussion until at least the second meeting thereafter. They may then be adopted by a two-thirds vote of a letter-ballot, conducted in the manner prescribed by the Council.

ARTICLE VIII. SECTIONS.

SECTION 1. To encourage and promote special investigations in any branch of science, members of the Academy may form Sections which shall be constituted as herein provided.

SEC. 2. For the formation of a Section written application shall be made to the Academy, at a regular meeting, by not less than six active members.

On the approval of this application by the affirmative vote of two-thirds of the members present at the next regular meeting, the Section shall be established and the names of the petitioners shall be recorded on its minutes as its founders.

SEC. 3. Sections may increase the number of their members by election, but only members of the Academy shall be elected members of any of the Sections.

SEC. 4. The officers of each Section shall be a Chairman and a Secretary, who shall be elected by its members at the first meeting of the Section, and subsequently at the first meeting in January of each year.

Sec. 5. The collections and books of each Section are the common property of the Academy. Donations of books and specimens made to or for any Section shall be received as donations to the Academy for the use of the Section.

Sec. 6. A report of the proceedings of each Section shall be submitted to the Academy at least once every month. Papers read before any Section with a view to publication by the Academy shall take the same course as papers read before the Academy.

Sec. 7. On all points not herein provided for, each Section shall be governed by the Constitution, By-Laws, and instructions of the Academy.

BY-LAWS.

I. REGULAR MEETINGS.

The regular meetings of the Academy shall be held on the first and third Monday evenings of every month, unless otherwise ordered by the Council.

II. SPECIAL MEETINGS.

Special meetings may be called by the President at his discretion, and shall be called by him on the written request of three or more members.

III. NOTICE OF MEETINGS.

The Recording Secretary shall send a notice of each meeting to every active member at least two days before such meeting.

IV. QUORUM.

Seven members shall constitute a quorum, but four members shall constitute a legal meeting for reading of papers.

V. ORDER OF BUSINESS.

The order of proceeding, at the regular meetings of the Academy, shall be as follows: —

1. Minutes of last meeting.
2. Report of the Council.
3. Reports of Committees.
4. Report of the Corresponding Secretary.
5. Donations to the Museum and Library.
6. Written Communications.
7. Oral Communications.
8. Deferred Business.
9. New Business.
10. Elections.
11. Proposals for Membership.
12. Adjournment.

VI. CORRESPONDING SECRETARY.

It shall be the duty of the Corresponding Secretary to conduct the correspondence and report to the Academy.

VII. TREASURER.

The Treasurer shall collect all moneys due the Academy; be custodian of all its funds, and pay such bills against the Academy as the Council shall approve. The Treasurer shall deposit the moneys and invest the funds of the Academy in its name and by and with the advice of the Council. Besides his annual report to the Academy, the Treasurer shall make such further reports and statements concerning the financial affairs of the Academy as the Council may from time to time require. Before entering upon his duties, the Treasurer shall give bond in such sum as may be required by the Council.

VIII. LIBRARIAN.

The Librarian shall take charge of all books belonging to or deposited with the Academy, and shall be responsible for the same; he shall keep a catalogue thereof, in which the names of contributors shall be inscribed; he shall superintend the distribution of all the publications of the Academy.

IX. COUNCIL.

The Council shall act as a publication committee; shall prepare a programme for each meeting, and may make rules and regulations for their own guidance, not inconsistent with the Constitution and By-Laws.

X. ELECTION OF OFFICERS.

A nominating committee of three active members who are not officers of the Academy shall be elected at the first regular meeting in December. This committee shall nominate candidates for all the offices for the ensuing year, and report the nominations at the following meeting, when other nominations may be made by any active member. The Recording Secretary shall mail to every active member a list of the nominees for office, at least ten days preceding the annual meeting. The polls shall be closed at 6 p. m. on the day of the annual meeting, after which the nominating committee shall count the ballots and announce the results to the Academy. A plurality of the votes cast shall suffice to elect.

XI. VACANCIES.

A vacancy in any office shall be filled by election conducted in the same manner as the annual election.

XII. ELECTION OF MEMBERS.

A candidate for admission to the Academy shall be proposed by not less than two members at any regular meeting. The proposal must then be referred to the Council, and if upon examination they shall find the candidate to be eligible and worthy of membership, they shall order the question as to his admission to be submitted to the Academy by ballot. If there be five votes in the negative, the candidate shall be rejected, and shall not be again voted upon for twelve months after such rejection. But if the number of negative votes be less than five, the candidate shall be elected, but shall not be considered a member until he shall have paid the initiation fee and the annual dues for the current year. Any failure to pay the initiation fee and annual dues within thirty days after the candidate has been notified of his election, shall work a forfeiture of all rights under said election, if the Council shall so determine. No entry shall be made on the record of the rejection of any candidate.

XIII. RESIGNATION OF MEMBERS.

Any member whose dues have been fully paid, may withdraw from the Academy by a written resignation. Non-payment of dues for one year or longer may be treated as equivalent to resignation; but before any member is dropped from the rolls for delinquency, he shall be entitled to not less than four weeks' notice.

XIV. EXPULSION OF MEMBERS.

Upon the written request of five members, that, for cause stated, any member be expelled, the Council shall consider the matter, and if they deem it best, shall advise the member that his resignation will be accepted. He shall, however, have the right to demand and shall be given a copy of the charges against him, and shall have a reasonable time to present a written defense. The Council may then pass finally upon the matter, and if resignation has not been tendered, or a satisfactory defense made, may by an affirmative vote of four of their number expel the member, in which case they shall notify him and the Academy of their action, and his name shall be at once dropped from the list of members.

XV. INITIATION FEE AND DUES.

Resident active members shall pay an initiation fee of five dollars, and annual dues of six dollars, payable at the beginning of each year. Non-resident active members shall pay an initiation fee of five dollars and annual dues of one-half the dues for resident active members, payable at the beginning of each year.

XVI. HONORARY MEMBERS AND PATRONS.

Honorary members and Patrons shall be recommended by the Council, and elected by the unanimous vote of the members present at any regular meeting.

XVII. PUBLICATIONS.

Patrons and all active members not in arrears shall be entitled to one copy of all the publications of the Academy issued subsequent to their election. Authors of papers shall be entitled to twenty extra copies of their individual papers.

XVIII. SALE OF REAL ESTATE.

The property conveyed to The Academy of Science of St. Louis on the eighteenth day of March, 1903, by Edgar R. Hoadley and Lavinia L. Hoadley, as a gift from Mrs. Eliza McMillan and William N. McMillan, shall not be mortgaged or voluntarily incumbered by the Academy of Science; and the said property shall not be sold, except with the consent of two-thirds of the members of the Academy of Science, obtained by letter ballot, in such manner as may be prescribed by the Council, and, when sold, the proceeds of the sale or so much thereof as may be necessary, shall be used to provide a suitable location and building for the use of The Academy of Science of St Louis.

XIX. AUTHORITY.

On all points of order and procedure, not provided for in the Constitution and By-Laws, *Robert's Rules of Order* shall be the authority.

XX. AMENDMENTS.

These By-Laws may be amended by a two-thirds vote of all the members present at any regular meeting, provided notice of the proposed amendment shall have been mailed to every member at least one week before the vote thereon is taken.

ABSTRACT OF HISTORY.

ORGANIZATION.

The Academy of Science of St. Louis was organized on the 10th of March, 1856, in the hall of the Board of Public Schools. Dr. George Engelmann was the first President.

CHARTER.

On the 17th of January following, a charter incorporating the Academy was signed and approved, and this was accepted by vote of the Academy on the 9th of February, 1857.

OBJECTS.

The act of incorporation declares the object of the Academy to be the advancement of science and the establishment in St. Louis of a museum and library for the illustration and study of its various branches, and provides that the members shall acquire no individual property in the real estate, cabinets, library, or other of its effects, their interest being usufructuary merely.

The constitution as adopted at the organization meeting and amended at various times subsequently, provides for holding meetings for the consideration and discussion of scientific subjects; taking measures to procure original papers upon such subjects; the publication of transactions; the establishment and maintenance of a cabinet of objects illustrative of the several departments of science, and a library of works relating to the same; and the establishment of relations with other scientific institutions. To encourage and promote special investigation in any branch of science, the formation of special sections under the charter is provided for.

MEMBERSHIP.

Members are classified as active members, corresponding members, honorary members and patrons. Active membership is limited to persons interested in science, though they need not of necessity be engaged in scientific work, and they alone conduct the affairs of the Academy, under its constitution. Persons not living in the city or county of St. Louis who are disposed to further the objects of the Academy, by original researches, contributions of specimens, or otherwise, are eligible as corresponding members. Persons not living in the city or county of St. Louis are eligible as honorary members by virtue of their attainments in science. Any person conveying to the Academy the sum of one thousand dollars or its equivalent becomes eligible as a patron.

Under the by-laws, resident active members pay an initiation fee of five dollars and annual dues of six dollars. Non-resident active members pay the same initiation fee, but annual dues of three dollars only. Patrons, and honorary and corresponding members, are exempt from the payment of dues. Each patron and active member not in arrears is entitled to one copy of each publication of the Academy issued after his election,

Since the organization of the Academy, 967 persons have been elected to active membership, of whom, at the present time, 292 are carried on the list. Four patrons, Mr. Edwin Harrison, Mrs. Eliza McMillan, Mrs. William Northrop McMillan and Mr. Henry W. Eliot, have been elected. The list of corresponding members (Vol. X., p. xii) includes 205 names, among which are the names of 102 persons known to be deceased.

OFFICERS AND MANAGEMENT.

The officers, who are chosen from the active members, consist of a President, two Vice-Presidents, Recording and Corresponding Secretaries, Treasurer, Librarian, three Curators, and two Directors. The general business management of the

Academy is vested in a Council composed of the President, the two Vice-Presidents, the Recording Secretary, the Treasurer, the Librarian and the two Directors.

The office of President has been filled by the following well-known citizens of St. Louis, nearly all of whom have been eminent in some line of scientific work: George Engelmann, Benjamin F. Shumard, Adolphus Wislizenus, Hiram A. Prout, John B. Johnson, James B. Eads, William T. Harris, Charles V. Riley, Francis E. Nipher, Henry S. Pritchett, John Green, Melvin L. Gray, Edmund A. Engler, Robert Moore, and Henry W. Eliot.

MEETINGS.

The regular meetings of the Academy are held at its building, 3817 Olive Street, at 8 o'clock, on the first and third Monday evenings of each month, a recess being taken between the meeting on the first Monday in June and the meeting on the third Monday in October. These meetings, to which interested persons are always welcome, are devoted in part to the reading of technical papers designed for publication in the Academy's Transactions, and in part to the presentation of more popular abstracts of recent investigation or progress. From time to time public lectures, calculated to interest a larger audience, are provided for in some suitable hall.

The following dates for regular meetings for the year 1904 have been fixed by the Council: —

Jan.	Feb.	Mar.	April.	May.	June.	Oct.	Nov.	Dec.
4	1	7	4	2	6		7	5
18	15	21	18	16		17	21	19

LIBRARY.

After its organization, the Academy met in Pope's Medical College, where a creditable beginning had been made toward the formation of a museum and library, until May, 1869, when the building and museum were destroyed by fire, the library being saved. The library now contains 14,893 books and 11,663 pamphlets, and is open during certain hours of the day for consultation by members and persons engaged in scientific work.

PUBLICATIONS AND EXCHANGES.

Thirteen thick octavo volumes of Transactions have been published since the organization of the Academy, and widely distributed. Two quarto publications have also been issued: one from the Archaeological section, being a contribution to the archaeology of Missouri, and the other a report of the observations made by the Washington University Eclipse Party of 1889. The Academy now stands in exchange relations with 576 institutions or organizations of aims similar to its own.

MUSEUM.

Since the loss of its first museum, in 1869, the Academy has lacked adequate room for the arrangement of a public museum, and, although small museum accessions have been received and cared for, its main effort of necessity has been concentrated on the holding of meetings, the formation of a library, the publication of worthy scientific matter, and the maintenance of relations with other scientific bodies.

RECORD.

From January 1, 1903, to December 31, 1903.

January 5, 1903.

President Eliot in the chair, twenty-two persons present.

The nominating committee reported that 138 ballots had been counted, and the following officers for 1903 were declared duly elected: —

President	Henry W. Eliot.
First Vice-President	D. S. H. Smith.
Second Vice-President	William K. Bixby.
Recording Secretary	William Trelease.
Corresponding Secretary	Ernest P. Olshausen.
Treasurer	Enno Sander.
Librarian	G. Hambach.
Curators	G. Hambach,
	Julius Hurter,
	A. H. Timmerman.
Directors	F. E. Nipher,
	Adolf Alt.

The President addressed the members present, on the condition of the Academy, and its work during the year 1902.*

The Treasurer submitted his annual report, showing invested funds to the amount of $6,500.00 and a current balance of $358.09 carried forward to the year 1903.†

The Librarian submitted his annual report.‡

The Council reported that the resignation of Mr. A. T. Primm, Jr., and Mr. G. R. Kline had been accepted, and that the following additions had been made to the exchange list: R. Accademia . . . degli zelanti, Acireale; Broteria, Lis-

---

* Transactions **12**: xxix.

† Transactions **12**: xxxi. ‡ Transactions **12**: xxxi.

bon; The Zoological Department of the University of California, Berkeley; and the Museum of the Institute of Arts and Sciences, Brooklyn.

On behalf of Mr. Hurter, who represented the Academy at the Fifth International Congress of Zoologists, held in Berlin in 1901, the Secretary presented to the library of the Academy a copy of the report of said Congress.

Mr. Julius Hurter presented for publication a paper on the herpetology of Missouri, illustrating his remarks by specimens.

Dr. Hermann von Schrenk presented some notes on the bitter-rot disease of apples, referring particularly to recent investigations and cultural experiments. He exhibited specimens of the cankers formed on apple limbs by the bitter-rot fungus (*Gloeosporium fructigenum*, Berk.) in various orchards, and of artificial cankers produced in apple trees at the Missouri Botanical Garden by inoculating branches with spores from apples affected with the bitter-rot disease, and spores from pure cultures of the fungus from cankers occurring naturally in the orchard. Cultures showing the perfect or ascus stage of the fungus were exhibited, and attention was called to the fact that up to date the perfect form had been found only in cultures and on several apples kept in the laboratory. He announced the discovery two weeks ago, by Mr. Perley Spaulding, of the perithecia and perfectly formed asci and ascospores of the bitter-rot fungus in several of the cankers produced on apple limbs from pure cultures of the bitter-rot fungus as well as from bitter-rot spores taken from cankers obtained in an affected orchard. This discovery is considered extremely important, as it demonstrates, for the first time, beyond question, that the bitter-rot fungus actually produces its perfect fruit in the cankers, and thereby strengthens the contention that the cankers on apple limbs are actually formed by the bitter-rot fungus. The asci are apparently as evanescent in the cankers as they are in cultures, and it is therefore not at all improbable that many of the supposed pycnidial spores found in both the natural and artificially produced cankers were really ascospores.

Drawings were exhibited showing the perithecia found in the cankers with asci and ascospores.

Mess. R. Kall and Th. Lange, of St. Louis, were elected to active membership.

Two persons were proposed for active membership.

January 19, 1903.

President Eliot in the chair, twenty-seven persons present.

The Council reported that the regular edition of the Academy's Transactions had been increased from 1,000 to 1,100; that the resignation of Mr. F. W. Biebinger and Mr. Victor Goetz had been accepted; and that exchange relations had been discontinued with the Anthropologische Gesellschaft, of Vienna.

Mr. W. L. Sheldon presented a summary of the progress in the science of ethics, since the publication of Darwin's "Descent of Man," in 1871.

Miss Mary J. Klem and Mr. Charles E. Rilliet, of St. Louis, were elected to active membership.

One person was proposed for active membership.

February 2, 1903.

Professor Nipher in the chair, twenty-four persons present.

The Council reported that the Academia Nacional, of Cordova, had been dropped from the exchange list, and that the Deutscher Verein Zum Schutze der Vogelwelt had been added to the list.

Dr. Tarleton H. Bean delivered an interesting illustrated address on the salmon and salmon fisheries of Alaska.

Dr. R. J. Terry reported on a case of right aortic arch in man — of relatively rare occurrence — and, with the aid of lantern slides and blackboard diagrams, indicated its peculiar features and morphological significance.

Dr. W. J. Gundelach, of St. Louis, was elected to active membership.

One person was proposed for active membership.

February 16, 1903.

Vice-President Smith in the chair, sixteen persons present.

Professor A. W. Greeley gave an account of recent experiments on the effects on protoplasm of variations in temperature and in the water content of the cells. It was shown that in the case of certain algae, protozoa, and the eggs of some marine invertebrates, a reduction of temperature gave rise to parthenogenetic spore formation or egg segmentation, as was also the case when, by suitable plasmolysis, water was withdrawn from the cells.

Mr. C. M. Prynne, of St. Louis, was elected to active membership.

March 2, 1903.

Dr. John Green in the chair, nine persons present.

Professor F. E. Nipher gave an account of his experiments in the production of ether waves by means of explosions. He is now using a brass tube, six feet long and one and one-third inch in diameter, for the explosive, which is laid in a train from end to end. This tube is placed within a large brass tube, one and three-eighths inch in diameter, which is wound with 25,700 windings of No. 25 copper wire. This coil is connected with a delicate D'Arsonval galvanometer. The coil is placed with its axis in the magnetic meridian. When gunpowder is exploded in the inner tube, the galvanometer gives indication of a change in permeability of the heated channel within the coil. The results were said to be as yet inconclusive, and the apparatus is to be somewhat modified with a view to making it more sensitive.

March 16, 1903.

Vice-President Smith in the chair, twenty-eight persons present.

Dr. H. M. Whelpley gave an account of the sacred pipestone quarries of the Upper Missouri, illustrating his remarks by the use of lantern slides, some of them from photographs taken by him at the quarries and others reproducing views published by Catlin and others.

APRIL 6, 1903.

President Eliot in the chair, twenty persons present.

The Council reported that the property now occupied by the Phillips School, on Olive Street between Spring and Vandeventer, had been purchased by Mrs. Eliza McMillan and her son, Mr. William Northrop McMillan, and deeded to the Academy as a memorial to the late William McMillian, who, at the time of his death, was a member of the Academy. The gift was referred to the Academy for appropriate action, with the recommendation on the part of the Council that Mrs. McMillan and her son be elected patrons of the Academy.

The President stated that in connection with this announcement by the Council he wished to say that it had been thought advisable by the Council that the gift, which was made for the purpose of giving the Academy a permanent home, should be surrounded by proper restrictions as to any future sale of the property which should insure the permanent possession of a home by the Academy, and that he trusted that action would be taken which should prevent the alienation at any time of this property without the contingent acquisition of an equal or better building for the Academy's use.

Professor Nipher said: —

Mr. President and Gentlemen of the Academy:

I cannot allow this occasion to pass without calling attention to the great significance of the announcement which has been made this evening.

Ever since the Academy was organized, in March, 1856, its work has been done under the most discouraging circumstances. It has never had a home. Its meetings have been held in the meeting room of the Board of Education, at a medical college, at Washington University, and in the rooms of the Missouri Historical Society. It has never had its own home, where it might make its valuable library and its collections of real service to the citizens of our city. During all these years of its existence the Academy has been collecting a library of scientific publications, in exchange with similar societies in all parts of the world. Our published Transactions have gone to every civilized land. We have certainly had the outward semblance of great scientific activity. There is no local Academy of Science in this country which can present a more creditable record of published work. Even during the civil war, when almost every educational interest suffered, a few working investigators aided by others who gave such support as they could give, continued to produce before this body their contributions to knowledge, and to publish them to the world in the Transactions of the Academy.

During all of this time these pioneers have been hoping to see this day. Year after year the President's annual report has called attention to the vital necessity of a fixed abiding place which we could own and control. Without this we could never hope to establish a public museum of Science, or to avail ourselves of our precious library.

And now the first great advance has been made. This gift to the cause we have been striving to uphold, could not have been more opportune. These enlightened patrons of higher learning have seen their opportunity, and they have volunteered their aid. The manner in which they have bestowed their bounty makes it doubly valuable and effective. They have made it impossible for us to honor them by any act within our power. They have become one with us in the cause which we have all labored to advance. May we not hope that they will permit us to enroll their names in our membership as Patrons of the Academy?

And this gift brings with it new obligations for us. We should now seek to establish an endowment fund, which will enable us to make our valuable collection of books and specimens fully available to the public. During the World's Fair we shall be under examination. Learned men from this and other lands will come among us. The great public will be here. The location of our new home is such that we cannot fail to attract the attention of vast numbers of our visitors. We should not only have a museum and library which will be an honor to our city, but it should be open to all. We wish to show that we have here, among the permanent institutions of our city, an Academy of Science which is dedicated to the advancement of human learning, and to the diffusion of knowledge among men. In this way we shall fittingly carry out the work which Mrs. William McMillan and her son, Mr. William Northrop McMillan, have so nobly begun.

The following resolutions, introduced by Professor Nipher and seconded by Dr. Ewing, were unanimously adopted, and the Secretary was instructed to communicate a copy of them to Mrs. McMillan and Mr. McMillan: —

Resolved, That the members of The Academy of Science of St. Louis most gratefully accept from Mrs. Eliza McMillan and Mr. William N. McMillan the gift of a permanent home for the Academy. We feel that this generous donation will infuse new life into the institution, and will insure its future usefulness. We pledge ourselves to use every effort to make it worthy of the confidence thus shown by the donors and to maintain the object of its founders, as expressed in the Act of Incorporation — "the advancement of science and the establishment in St. Louis of a museum and library for the illustration and study of its various branches."

Resolved, by the members of The Academy of Science of St. Louis, that the property conveyed on the 18th day of March, 1903, by Edgar R. Hoadley and Lavinia L. Hoadley, to The Academy of Science of St. Louis, which property is the gift of Mrs. Eliza McMillan and William N. McMillan, shall not be mortgaged or incumbered so long as it remains the property of The Academy of Science.

Resolved, further, that the property shall not be sold except by a two-thirds vote of the members of The Academy of Science of St. Louis by letter-ballot in the manner prescribed by the Council, and that when sold, the proceeds of the sale, or as much thereof as may be necessary, shall be used to provide a suitable location and building for the uses of The Academy of Science.

Mrs. Eliza McMillan and Mr. William Northrop McMillan were elected patrons of the Academy, on nomination of the Council.

Professor A. S. Chessin presented the following communication on the strains and stresses in a rotating thin circular disc: —

The problem of determining the strains and stresses in a rotating disc or, as it is commonly known, the problem of the fly-wheel, is still an open one so far as a general solution is considered. The present paper deals only with very thin discs but the method of obtaining a solution may be readily extended to the more general problem.

Let the axis of the disc be the axis of z, and let r be the radius vector to any point drawn perpendicular to this axis, and θ the angle between the direction of r and a fixed plane through the axis; also let u and w be the displacements in the direction of the radius and the axis; finally let ρ be the density of the solid, ω the angular velocity of its rotation and $2h$ its thickness. If the disc be isotropic the stresses are

$$(1)\qquad \begin{aligned} \widehat{rr} &= \lambda\Delta + 2\mu\frac{\partial u}{\partial r}, \\ \widehat{\theta\theta} &= \lambda\Delta + 2\mu\frac{u}{r}, \\ \widehat{zz} &= \lambda\Delta + 2\mu\frac{\partial w}{\partial z}, \\ \widehat{rz} &= \mu\left(\frac{\partial u}{\partial z} + \frac{\partial w}{\partial r}\right), \end{aligned}$$

where $\Delta = \frac{\partial u}{\partial r} + \frac{u}{r} + \frac{\partial w}{\partial z}$; and the problem consists in integrating the differential equations

$$(2)\qquad \begin{aligned} &(2\mu + \lambda)\frac{\partial}{\partial r}\left(\frac{\partial u_1}{\partial r} + \frac{u_1}{r}\right) + \mu\frac{\partial^2 u_1}{\partial z^2} + (\mu + \lambda)\frac{\partial^2 w}{\partial r \partial z} = 0 \\ &\frac{\mu}{r}\frac{\partial}{\partial r}\left(r\frac{\partial w}{\partial r}\right) + (2\mu + \lambda)\frac{\partial^2 w}{\partial z^2} \\ &\qquad\qquad + (\mu + \lambda)\frac{\partial}{\partial z}\left(\frac{\partial u_1}{\partial r} + \frac{u_1}{r}\right) = 0 \end{aligned}$$

where the function

$$(3)\qquad u_1 = u - \frac{\rho\omega^2}{8(2\mu + \lambda)}r^3$$

has been introduced in place of u. At the same time the following surface conditions must be satisfied:

I. Full disc $(0 \leqq r \leqq R)$.

$$\widehat{rr} = 0 \text{ for } r = R,$$

$$\widehat{zz} = 0 \text{ for } z = \pm h,$$

$$\widehat{rz} = 0 \text{ for } r = R \text{ and for } z = \pm h.$$

II. Perforated disc $(R_1 \leqq r \leqq R_2)$.

$$\widehat{rr} = 0 \text{ for } r = R_1 \text{ and for } r = R_2,$$

$$\widehat{zz} = 0 \text{ for } z = \pm h,$$

$$\widehat{rz} = 0 \text{ for } r = R_1, \text{ for } r = R_2, \text{ and for } z = \pm h.$$

It can be shown that the following formulas

$$(4)\qquad w = \sum_k \left[A_k J_o(\xi_k r) + B_k K_o(\xi_k r)\right]\left(e^{\xi_k z} - e^{-\xi_k z}\right)$$

$$-\frac{\mu + \lambda}{2(2\mu + \lambda)}\sum_k \left[A_k^1 r J_1(\eta_k r) + B_k^1 r K_1(\eta_k r)\right]\left(e^{\eta_k z} - e^{-\eta_k z}\right)$$

$$(5)\quad u_1 = cr - \sum_k \left[A_k J_1(\xi_k r) + B_k K_1(\xi_k r) \right] \left(e^{\xi_k z} + e^{-\xi_k z} \right)$$

$$+ \sum_k \frac{1}{\eta_k} \left[A_k^1 J_1(\eta_k r) + B_k^1 K_1(\eta_k r) \right] \left(e^{\eta_k z} + e^{-\eta_k z} \right)$$

$$- \frac{\mu + \lambda}{2(2\mu + \lambda)} \sum_k \left[A_k^1 r J_o(\eta_k r) + B_k^1 r K_o(\eta_k r) \right] \left(e^{\eta_k z} + e^{-\eta_k z} \right)$$

give a general solution of the equations (2) where the coefficients A, B, A^1, B^1 are determined from surface conditions. For the purposes of this paper, however, a simpler method may be pursued. Namely, formulas (4) and (5) show that the general solution may be presented in the form

$$(6)\quad \begin{aligned} u_1 &= u_{10} + u_{11} z^2 + u_{12} z^4 + \ldots \\ w &= w_0 z + w_1 z^3 + w_2 z^5 + \ldots \end{aligned}$$

where u_{10}, u_{11}, ..., w_0, w_1, ... are functions of r only. Substituting these expressions of u_1 and w in (2) we find that this system of differential equations may be replaced by the following one

$$(7)\quad \begin{aligned} &(2\mu + \lambda) \frac{d}{dr} \left(\frac{du_{10}}{dr} + \frac{u_{10}}{r} \right) + 2\mu u_{11} + (\mu + \lambda) \frac{dw_0}{dr} = 0, \\ &(2\mu + \lambda) \frac{d}{dr} \left(\frac{du_{11}}{dr} + \frac{u_{11}}{r} \right) + 12\mu u_{12} + 3(\mu + \lambda) \frac{dw_1}{dr} = 0, \end{aligned}$$

....

$$(8)\quad \begin{aligned} &\frac{\mu}{r} \frac{d}{dr} \left(r \frac{dw_0}{dr} \right) + 6(2\mu + \lambda) w_1 \\ &\qquad + 2(\mu + \lambda) \left(\frac{du_{11}}{dr} + \frac{u_{11}}{r} \right) = 0, \\ &\frac{\mu}{r} \frac{d}{dr} \left(r \frac{dw_1}{dr} \right) + 20(2\mu + \lambda) w_2 \\ &\qquad + 4(\mu + \lambda) \left(\frac{du_{12}}{dr} + \frac{u_{12}}{r} \right) = 0, \end{aligned}$$

....

while the surface conditions for $z = \pm h$ become

$$(9) \quad 0 = h\frac{dw_0}{dr} + h^3\frac{dw_1}{dr} + \ldots\ldots + 2u_{11} + 4h^2u_{12} + \ldots.$$

$$(10) \frac{\lambda\rho\omega^2}{2(2\mu+\lambda)}r^2 = \lambda\left(\frac{du_{10}}{dr} + \frac{u_{10}}{r}\right) + \lambda h^2\left(\frac{du_{11}}{dr} + \frac{u_{11}}{r}\right) + \ldots.$$
$$+ (2\mu+\lambda)w_0 + 3(2\mu+\lambda)h^2w_1 + \ldots.$$

For very thin discs we may neglect the powers of z and h higher than the first. Then, to determine u_{10} and w_0, we have the first of the equations (7) together with the surface conditions

$$(9\text{ bis}) \qquad 0 = \frac{dw_0}{dr} + 2u_{11},$$

$$(10\text{ bis}) \quad \frac{\lambda\rho\omega^2}{2(2\mu+\lambda)}r^2 = \lambda\left(\frac{du_{10}}{dr} + \frac{u_{10}}{r}\right) + (2\mu+\lambda)\,w_0,$$

from which we can eliminate u_{11}. The problem now is very simple and we give below only the results.

I. Full disc.*

$$u = \frac{\rho\omega^2}{8\mathrm{E}}(1-\sigma^2)\,r\left[\frac{3+\sigma}{1+\sigma}R^2 - r^2\right] \qquad ,$$

$$w = -\frac{\rho\omega^2}{2\mathrm{E}}\sigma(1+\sigma)z\left[\frac{3+\sigma}{2(1+\sigma)}R^2 - r^2\right] \qquad ;$$

$$\widehat{rz} = 0; \quad \widehat{zz} = 0; \quad \widehat{rr} = \frac{\rho\omega^2(1+\sigma)(3+\sigma)}{4\mathrm{E}}(R^2 - r^2);$$

$$\widehat{\theta\theta} = \frac{\rho\omega^2(1+\sigma)(3+\sigma)}{4\mathrm{E}}\left[R^2 - \frac{5-6\sigma}{7-2\sigma}r^2\right].$$

---

* In these formulas Young's modules (E) and Poisson's ratio (σ) have been introduced. The results (for full discs) are identical with those obtained by Mr. Chree (Camb. Phil. Soc. Proc. 1890) if in his formulas we discard the terms of the order of h^2 and higher. However, the general solution as obtained above, is entirely different from Mr. Chree's and can be made to satisfy all surface conditions, which Mr. Chree's solution does not do.

II. Perforated disc.

$$u = \frac{\rho\omega^2(1-\sigma^2)}{8E} r \left[\frac{3+\sigma}{1+\sigma}(R_2^2 + R_1^2) - r^2\right] + \frac{\rho\omega^2(1+\sigma)(3+\sigma)}{8E}\frac{R_1^2R_2^2}{r}$$

$$w = -\frac{\rho\omega^2\sigma(1+\sigma)}{2E} z \left[\frac{3+\sigma}{2(1+\sigma)}(R_2^2 + R_1^2) - r^2\right]$$

$$\widehat{rz} = 0;\ \widehat{zz} = 0;\ \widehat{rr} = \frac{\rho\omega^2(1+\sigma)(3+\sigma)}{4E}(R_2^2 + R_1^2 - r^2) - \frac{\rho\omega^2(1+\sigma)(3+\sigma)}{4E}\frac{R_1^2R_2^2}{r^2}$$

$$\widehat{\theta\theta} = \frac{\rho\omega^2(1+\sigma)(3+\sigma)}{4E}\left[R_2^2 + R_1^2 - \frac{5-6\sigma}{7-2\sigma}r^2\right] + \frac{\rho\omega^2(1+\sigma)(3+\sigma)}{4E}\frac{R_1^2R_2^2}{r^2}.$$

Professor F. E. Nipher reported that he had apparently succeeded in producing a distortion of a magnetic field by means of explosions. The apparatus used was a transformer consisting of concentric coils wound upon brass tubes. The outer tube was five inches in diameter and six feet long, wound with over four thousand windings of No. 16 wire. This coil was traversed by a continuous current from a storage battery. Within this and separated from it by an air-space of an inch, is a secondary coil of equal length having over twenty-five thousand windings of No. 25 wire. This coil is connected to a D'Arsonval galvanometer. Within the tube on which this coil is wound is a smaller brass tube within which a train of black gunpowder is laid. This tube is open at both ends, and has practically no recoil when the explosion is made. When hung by a bifilar suspension on cords ten feet in length, the recoil is about an inch. When the exciting current is small compared with the capacity of the battery, the galvanometer reading is very steady. When the train is exploded a sudden and marked throw of the galvanometer results, which could be accounted for by an increase in the permeability of the long explosion chamber. The deflection reverses when the field is reversed. The hot gases liberated in the explosion are all diamagnetic, and tend to decrease the observed effect. In two cases the galvanometer deflection was in the opposite direction from that stated above, and this is being further inquired into. When seven tubes between the two coils are simultaneously exploded, only slight effects could be obtained, and these deflections are wavering, or to and fro, in character. A wire was threaded through the inner combustion tube, through which a current of three amperes was passed. This circuit was opened and closed with no visible effect. The galvanometer circuit is shielded by tin-foil, which is also connected with the explosion tube, and grounded. Sparks an inch long to the tin-foil produce no result. When the explosion tube is removed from the transformer, and taken near the galvanometer, or the storage battery, no deflection is produced by the explosion.

An explosive mixture of gases from water electrolysis under atmospheric pressure produces a much less violent explosion, and produces a correspondingly less effect. The scale reading of the galvanometer changes by over twenty divisions with the heaviest explosions, and an exciting current of 0.6 ampere. With smaller explosions or feebler current, the effect is diminished. No deflections can be produced by striking the table upon which the transformer rests, or by striking the transformer itself, even when it moves slightly under the blow. The secondary and primary coils are held rigidly in fixed position with respect to each other.

Arrangements have now been made to place the explosion tube in the focal line of a parabolic cylinder of metal, the galvanometer coil being in the focal line of a similar mirror. Either or both are to be surrounded by an exciting coil.

This line of research was suggested by Young's account of his observation of five solar outbursts in 1872, which were each accompanied by sharp fluctuations in the magnetic tracings at Kew and Stonyhurst. Since the experiments began, volcanic explosions have produced such ether waves, which have been simultaneously recorded over the continents of Europe and America.

April 20, 1903.

President Eliot in the chair, twenty-two persons present.

Professor J. A. Holmes gave an account of some of the efforts that are being made in the United States to preserve the forests and other natural features of the country, showing what is being done for the preservation of some of the great scenic features and particularly what the National Government is doing in the establishment of national parks and forest reserves, and in the protection of their forests. The lecture was illustrated by a series of lantern slides.

Dr. Alexander N. De Menil was elected to active membership.

May 4, 1903.

President Eliot in the chair, thirteen persons present.

Mr. H. A. Wheeler gave an account, illustrated by several lantern slides and some of the ejected material, of the active Mexican volcano Colima, in which it was shown that the material now being ejected is a trachyte or belongs to the acid series of lavas, while the basal plain of the volcano is basalt, which is basic, and resting on volcanic tufa. It was pointed out that this sequence reverses the Richtopen order, from which it was considered probable that there had been other centers of lava outflow besides the now visible vents of Mt. Colima (active) and Mt. Zapotlan (inactive). Samples of the ash from the eruption of February 28, collected at Tuxpan, some 25 miles from the crater, by Prof. Trelease, contained 62.5% silica, according to the analysis of Wm. M. Chauvenet.

Mr. Trelease, who had been near the base of the mountain during its recent activity, made a few remarks in connection with the paper.

The following amendments to the By-Laws, recommended by the Council, and notice of which was mailed by the Secretary to each member on April 23, were adopted by a unanimous vote of the members present.

By-Laws 18 and 19 were changed respectively to 19, AUTHORITY, and 20, AMENDMENTS; and the following new By-Law was adopted: —

XVIII. Sale of Real Estate.

The property conveyed to The Academy of Science of St. Louis on the eighteenth day of March, 1903, by Edgar R. Hoadley and Lavinia L. Hoadley, as a gift from Mrs. Eliza McMillan and William N. McMillan, shall not be mortgaged or voluntarily incumbered by the Academy of Science; and the said property shall not be sold, except with the consent of two-thirds of the members of the Academy of Science, obtained by letter ballot, in such manner as may be prescribed by the Council, and, when sold, the proceeds of the sale or so much thereof as may be necessary, shall be used to provide a suitable location and building for the use of The Academy of Science of St. Louis.

One person was proposed for active membership.

May 18, 1903.

President Eliot in the chair, fifty persons present.

Dr. C. Barck gave a detailed account of the Grand Cañon of the Colorado, with lantern illustrations, and reported the first deliberate crossing of the Cañon, by Mr. James and himself, in 1901. He stated that, starting from Bass's camp, about twenty-four miles west of the Bright Angel hotel, they had reached "Point Sublime" on the northern rim on the fifth day, after some difficult traveling, the return taking three days.

Dr. Robert Luedeking, of St. Louis, was elected to active membership.

One person was proposed for active membership.

June 1, 1903.

President Eliot in the chair, fifteen persons present.

Drs. B. M. Bolton and D. L. Harris exhibited sections cut after infiltration with agar-agar, and described the use of this material for imbedding purposes as follows: —

Tissues can be readily hardened and imbedded for cutting into sections in a hot solution of agar-agar containing formalin. The proportions of the mixture which have so far yielded the best results are nine parts of a five per cent aqueous solution of agar-agar to one part formalin. This mixture can be prepared beforehand and kept indefinitely in an air-tight vessel. The agar-agar should be boiled for several hours, and after the addition of the formalin allowed to clear by sedimentation. The bits of tissue to be imbedded are placed in a wide test-tube or wide-mouth vial containing the mixture previously melted. This is kept at 65–70° C. for an hour or longer, and the tissues are ready to be blocked. After attaching to blocks they are placed in strong or absolute alcohol for an hour or two and can then be cut. It is important not to use dilute alcohol. The tissues are stuck to the blocks by means of the agar-agar itself and adhere as soon as the agar becomes cold. No previous hardening of the tissues is at all necessary, fresh tissues can be placed at once into the hot agar-agar-formalin mixture — in fact, fresh tissue is more desirable than that which has been previously hardened, though this can be readily imbedded by this method. But the main advantage of the method, aside from its convenience and simplicity, is the fact that the cells of the tissues are not at all contracted or shrunken, and the ordinary methods of hardening have this effect more or less. With sections prepared from fresh tissues by this method the cell-protoplasm fills out the membrane fully, and the granules of the protoplasm, the nuclei, and the cell contours are remarkably distinct. The whole process, hardening, imbedding and cutting, does not occupy more than three or four hours, where the tissues are not larger than about one centimeter in diameter.

Professor A. W. Greeley presented the results of an investigation of the reactions of Paramecia and other protozoa to chemical and electrical stimuli.*

Two persons were proposed for active membership.

---

* Science n. s. **17**: 980.

October 19, 1903.

President Eliot in the chair, thirty-five persons present. This was the first meeting held in the new Academy Building, 3817 Olive street.

The Council reported that the following names had been dropped from the membership roll: J. H. Boogher, M. F. Engman, E. Grebe, A. Habermaas, A. A. Henske, J. Maserang, Jr., C. H. Stone, O. Sutter, and O. M. Wood; that the resignation of Professor A. S. Chessin had been accepted; and that the Zoological Institute, Cagliari, had been added to the exchange list.

Professor F. E. Nipher gave an abstract of the results of his paper on the "Law of Nebular Contraction," which has just been published in the Transactions. He also remarked that the molecular conditions in nebulae of different gases were being examined, and some very interesting results are at once evident. If a series of nebulae of various gases have the same mass internal to the same radius, the average molecular velocities would be the same for all gases. The velocity which would enable a molecule to escape from the nebula is 2.71 times the average molecular velocity, and this ratio is constant for all parts of the nebula. If the entire solar system formed the core of such a nebula, and the mass of the solar system extended to Neptune's orbit, the density at that distance from the center of the nucleus would be less than that in a Crookes tube. This opens up some very interesting questions concerning the history of such a mass. It would appear that such a gravitating mass would lose some heat by the escape of the more rapidly moving molecules, as well as by radiation.

Professor E. H. Keiser read a paper on a method of determining the amount of lime in cements. He finds that this can be done by determining the amount of water absorbed. By measuring this absorption in samples containing known amounts, the precautions to be taken in manipulation have been found. The determination only requires about twenty minutes.

Professor F. E. Nipher presented a diagram on which was drawn the curve of speed of the trotting horse. This curve represents the equation published by him twenty years ago. On the same diagram was shown a belt of observed values representing the performance of every horse who has broken the speed record since 1845. In some cases a single horse has broken the record several times in the same year. All such observations were included. The points representing these observations formed a belt within which was the curve of predicted speed. The agreement was considered very satisfactory.

Mess. Edward Mallinckrodt, Jr., Gustav Nautze, and A. Raphael, were elected to active membership.

Five persons were proposed for active membership.

November 2, 1903.

Vice-President Smith in the chair, thirty-five persons present.

The following papers were presented, accompanied by abstracts: B. F. Bush, A new genus of grasses; J. A. Harris, Polygamy in Solanum; and J. A. Harris, The germination of Pachira, with a note on the names of two species.

Mr. Trelease read an address on The Academy of Science of St. Louis — a biography.*

Mess. J. A. Harris, H. C. Irish, W J McGee and Oscar Riddle, of St. Louis, and Dr. Jos. Zawodny, of Schloss Lobes, Mscheno-Melnik, Bohemia, were elected to active membership.

November 16, 1903.

Vice-President Smith in the chair, twenty-two persons present.

The Council reported the death of Dr. J. B. Johnson and Mr. I. W. Morton.

---

* Popular Science Monthly. 64: 117.

Professor A. W. Greeley presented a report on experiments on the nature of the contraction of muscle. These experiments were undertaken with the view of working out more fully the mechanism involved in the galvanotropic and chemotropic reactions of Paramecia in acid and alkaline media, as described in Mr. Greeley's report before the Academy last spring. In the experiments on the contraction of muscle, it was found that when the medusa, *Goniomemius*, was exposed to the constant current, rhythmical contraction began always on the cathodal side when the medusa was immersed in normal sea water, but that the contractions began on the anodal side in acidulated sea water. Likewise it was shown that acids induce a phase of contraction, alkalis a phase of relaxation. It was suggested that these results may throw some light on the supposed electrical nature of muscle contraction, and that they offer additional evidence toward the conclusion that the charge carried by the protoplasmic particles depends on certain definite chemical conditions of the surrounding medium.

Two persons were proposed for active membership.

December 7, 1903.

Vice-President Smith in the chair, forty persons present.

The Chairman stated that because of the necessity of providing the new building with fuel, furniture, lighting appliances, etc., the expenses of moving, added insurance, the final payment on the Yandell collection, and other unusual expenses, the Council was confronted by the necessity of temporarily raising some $1,750.00, which it was hoped could be repaid in a few months, after suitable arrangements had been made for securing revenue by renting meeting accommodations in the Academy Building to other societies. He stated that as this was a very important matter, the Council wished action on it to be taken by the Academy. On motion, the Council was authorized, by a unanimous vote, to raise the necessary sum by borrowing on the securities representing invested funds, it being understood that no lien of any kind should be attached to the real property of the Academy.

The Council reported the resignation of Mess. Frank Thilly, J. M. Holzinger and Arthur Winslow.

Dr. Adolf Alt read an interesting paper entitled What is a cataract? — illustrated by diagrams and lantern views from specimens selected from his personal collection.

Dr. H. M. Whelpley exhibited a minute particle of radium, the remarkable activity of which was beautifully shown in a special form of hand apparatus now on the market for such demonstration.

In accordance with the By-Laws of the Academy, a committee, which consisted of Mess. Krall, Barck and Widmann, was elected to nominate officers for the year 1904.

Dr. A. E. Eycelshymer and Mr. Hiram Lloyd, of St. Louis, were elected to active membership.

Four persons were proposed for active membership.

December 21, 1903.

Vice-President Smith in the Chair, twenty-eight persons present.

The Council reported that the resignation of Mess. A. H. Muegge and Oscar Riddle had been accepted, and that, under the instructions given at the last meeting, arrangements had been made for borrowing $1,750.00 for sixty days, on investment securities.

The nominating committee reported the following list of candidates for the year 1904: —

President	W. K. Bixby.
First Vice-President	William Trelease.
Second Vice-President	Adolf Alt.
Recording Secretary	Ernest P. Olshausen.
Corresponding Secretary	August Hunicke.
Treasurer	Enno Sander.
Librarian	G. Hambach,
Curators	G. Hambach,
	Julius Hurter,
	Frank Schwarz.
Directors	F. E. Nipher,
	Jos. Spiegelhalter.

Other nominations were called for, but none were made.

Mr. Robert Moore presented, with diagrams, a paper entitled Vital statistics of St. Louis from 1840 to 1902.

On motion, the President was authorized to sign a petition to the President of the United States for aid in preserving groves of the Calaveras big trees, which was presented by the Outdoor Art League.

Mr. T. W. Allen, Mr. F. W. Drosten, Dr. H. M. Starkloff and Dr. Hugo Summa were elected to active membership.

Two persons were proposed for active membership.

Reports of Officers for the Year 1903,

submitted January 4, 1904.

The First Vice-President, Dr. D. S. H. Smith, addressed the Academy as follows: —

In the absence of the President, it becomes my duty to lay before you a summary of the doings of the Academy of Science for the year 1903.

Sixteen meetings were held in 1903, with average attendance of 25.

Fifteen meetings were held in 1902, with average attendance of 21.

Total attendance in 1903	406
Total attendance in 1902	314
Increase for 1903	92

In 1903 the unusual attendance of 50 at the second meeting in May was due to the announcement of Dr. Barck's account of his crossing of the Grand Cañon of the Colorado. There has been a noticeable increase in attendance at the meetings since the removal of the Academy to its new home, the largest number (40) at the first December meeting, when Dr. Alt gave us his paper on Cataract.

Membership December 31, 1903	...	...	292
Elections for the year	...	23	
Losses " " "	...	24	
By death	4	..	
By resignations	20	...	
Net loss for the year	...	1	

The active members are classified as follows. —

Patrons... ...	3	
Resident members... ...	221	
Non-resident members... ...	68	
Total...		292

No corresponding members have been elected for some years past.

Nine papers were published in 1903, eight by resident members and one by a non-resident member.

Ten papers were published in 1902, seven of them by non-resident members.

Of the papers published in 1903, two were on mathematical subjects, one was on a chemical subject, three were on botanical subjects, one was on a zoological subject, one was on a paleontological subject, and one on a philosophical subject.

The reports of the Treasurer and of the Librarian have already been submitted to you.

As matter for special consideration this evening, I beg leave to invite your attention to the financial needs of the Academy.

In the spring of 1903 this house and lot were conveyed to the Academy by Mrs. William McMillan and her son, Mr. William Northrop McMillan. It was the free gift of a home for the Academy, untrammeled by any conditions. The generous lady and her son had every confidence that the members of the organization would care for the property with a wise economy. Whatever limitations were placed on the ownership were placed by the Academy itself.

As soon as the conveyance was legally completed by the proper deed, Mr. Eliot, the President of the Academy, announced to the Council that he would give $5,000.00 to be expended in necessary repairs and rehabilitation and furnishing of the house. Mr. Eliot's modesty has made him unwilling that anything should be said about this generous gift, but the necessities of this sketch and justice to the Academy compel me to refer to it. We are unwilling to accept so handsome a donation without being given an opportunity to express our grateful appreciation of it. Immediately upon Mr. Eliot's announcement, the Council appointed a committee, of which Mr. Eliot was chairman, for the disbursement of the $5,000.00 in accordance with the terms of the gift. This has now been accomplished, and proper vouchers showing the various items of expenditure have been rendered to the Council, and placed by the Council in the hands of the Treasurer.

In moving to these more ambitious quarters we necessarily increase our expenses largely. The Assistant to the Librarian and the Janitor together cost us over $1,000.00 a year. Then there are the bills for lighting and heating the house and the expense of our annual publication, along with a multitude of small disbursements which amount to a considerable sum in the aggregate. The annual dues of members, the interest upon a sum of $6,500.00, and rentals to societies of a scientific character, are our only sources of revenue. What these rentals shall be we cannot determine. Miss Phillips, who occupied the building as a school until its acquisition by the Academy, paid an annual rental of about $1,000.00.

In frequent discussions and comparisons of ideas by members of the Council for several years past, there has been a unanimity of opinion that if the Academy ever became possessed of a home, it would be necessary to obtain an endowment fund for its support, and that that fund should not be less than $50,000.00.

I am here to-night to submit a plan for securing this amount of money. The plan, if approved by you, will be carried out in its details by the Council.

1st. The Council shall appoint three members to act as an Endowment Fund Committee. This Committee shall receive and account for all donations and subscriptions to the Endowment Fund, and shall invest the same in securities to be approved by the Council.

2d. Thirty members of the Academy are to be appointed as Chairmen of Soliciting Committees. Each Chairman may select five (5) Committeemen to complete his Committee. These selections need not of necessity be members of the Academy. It shall be the task of each Committee to collect $1,000.00.

3d. When $30,000.00 shall have been collected and placed in the hands of the Endowment Fund Committee, a member of the Academy will raise $10,000.00.

While these are the main and definite features of the plan, it does not stop here. I may take it for granted that every member of the Academy wishes it well and is willing to do something to assist it in promoting its aims and the purposes for which it was organized. Let each member who is not selected to serve on a Soliciting Committee consider himself a committee of one to raise $50.00. It is difficult for me to believe that we have in our membership anyone who has not ten friends and acquaintances who would contribute $5.00 apiece to the support of an institution with such noble and unselfish aims as this Academy.

Our membership should be increased to 500. Every member who brings in a new member is practically contributing $100.00 to the Academy — for the annual dues of $6.00 are equivalent to 6 per cent per annum on $100.00.

Such, gentlemen, is the plan which I submit for your consideration. This or some better scheme must be adopted without delay, for the need of money is urgent. We have had to borrow $1,750.00, and in sixty days this loan must be met. This Endowment Fund comes home to every member of the Academy as a personal matter, and I urge most earnestly upon every man to throw apathy and indifference to one side and to do his share towards securing the fund for this institution.

The Treasurer reported as follows: —

Receipts.

Balance from 1902	$ 358 09	
Gift of Henry W. Eliot	5,000 00	
Capital released	3,000 00	
Interest on invested money	372 50	
Rent from Academy building	405 00	
Borrowed on note	1,750 00	
Membership dues	1,552 10	
		$12,437 69

EXPENDITURES.

Rent	$ 491 35	
Publication of Transactions	897 01	
Mailing Transactions and library expense, above sales of Transactions	586 66	
Sundry expenses	533 27	
Payment, account Yandell collection	295 00	
Capital reinvested, and premium	3,023 50	
Improvements to property	5,929 47	
Insurance	118 00	
Balance to 1904	563 43	
		$12,437 69

INVESTED FUND.

Invested on security	$6,500 00	
Less note covered by securities	1,750 00	
Net invested fund		$4,750 00

The Librarian reported that during the year exchanges had been received to the number of 402 volumes and 646 pamphlets, an increase of 54 numbers as compared with 1902; that during the year the Transactions of the Academy were distributed to 575 societies or institutions, an increase of 6 as compared with the preceding year; and that the expense of his office for 1903 had amounted to $121.49, against which was to be credited $27.97 received from the sale of publications.

Transactions of The Academy of Science of St. Louis.

VOL. XIII. No. 1.

REVISION OF THE BLASTOIDEAE, WITH A PROPOSED NEW CLASSIFICATION, AND DESCRIPTION OF NEW SPECIES.

G. HAMBACH.

Issued November 4, 1903.

REVISION OF THE BLASTOIDEAE, WITH A PROPOSED NEW CLASSIFICATION, AND DESCRIPTION OF NEW SPECIES.*

G. Hambach.

ERRATA.

p.	7.	l. 5 read for	lumen is	"lumina are."	
"	9.	" 18 " "	oval	"oral."	
"	12.	" 32 " "	Fig. 5	"Figs. 8, 10 and 11."	
"	14.	" 20 " "	Plate II fig. 2, 3, 5	"Plate II Fig. 3."	
"	31.	" 28 " "	Maccoy	"M'Coy."	
"	47.	" 22 " "	Codastus	"Codaster."	
"	47.	footnote read for	ralated	"related."	
"	49.	l. 10 read for	impossibie	"impossible."	
"	51.	l. 13 & 15 read for	canedayi	"cassedayi."	
"	53.	" 22 read for	ambulacria	"ambulacra."	
"	55.	" 18 " "	plicable	"plicated."	
"	55.	" 35 " "	prominent	"promising."	
"	59.	" 18 omit comma			

Explanation to Pl. II. No. 5 add "enlarged four times."
" " " " 11 " "in a Codaster."
" " Pl. IV. " 6 read for pyramidalis "bipyramidalis."

greater degree of certainty than has been the case hereto-

* Presented by title to The Academy of Science of St. Louis, June 3, 1901.

† So is, for example, the figure of *Granatocrinus melonoides* on Pl. IX., Vol. V. of the Illinois Geological Survey absolutely a false representation of this species although it was drawn by the eminent palaeontologist, Meek.

REVISION OF THE BLASTOIDEAE, WITH A PROPOSED NEW CLASSIFICATION, AND DESCRIPTION OF NEW SPECIES.*

G. Hambach.

Our knowledge of the morphology of the Blastoideae has made such progress during the last two decades that a revision is highly desirable; first, because all late publications on this subject, even the newest text-books on palaeontology, repeat old and erroneous conceptions which are, to a great extent, accompanied by incorrect illustrations,† and secondly, because of the inadequacy of the present classification, which is almost an arbitrary one, not based on permanent anatomical differences, nor ontogenetic peculiarities. New material which I have collected during this period, and also that which has kindly been intrusted to me for comparison with my own, of which I may mention the whole collection of Blastoideae belonging to the Smithsonian Institution, numbering 1038 specimens, also a very valuable collection of Mr. F. A. Sampson, corroborate the suppositions expressed in my first paper, on "The Anatomy of the Blastoideae," and add new facts to those already known.

Blastoideae are known from the following countries besides America: England, Belgium, Germany, Spain, France, Russia and Australia. The main bulk of the material belongs to America, however, and especially to the family Pentremidae. In no other family do we find such abundant and such well preserved material as we do in this family; which fact allows us to form conclusions with a greater degree of certainty than has been the case hereto-

* Presented by title to The Academy of Science of St. Louis, June 3, 1901.

† So is, for example, the figure of *Granatocrinus melonoides* on Pl. IX., Vol. V. of the Illinois Geological Survey absolutely a false representation of this species although it was drawn by the eminent palaeontologist, Meek.

fore, because such families as Codasteridae, Olivanidae, etc. are known to occur only in such limited quantity and in such a poor state of preservation that conclusions regarding their internal structure will stand no comparison with that of the Pentremidae and leave a large and open field for future investigation.

The present revision and the anatomical descriptions herein given are based mainly on *Pentremites sulcatus*, *florealis* and *conoideus*, not because they are more abundantly represented than any other species (for *Pentremites godoni* occurs in great numbers in Pulaski Co., Kentucky, as well as at Huntsville, Alabama), but the preservation of *Pentremites sulcatus* is so excellent that we often find the most delicate and fragile organs preserved, especially in those specimens which were imbedded in a kind of clayey substance. I think it is not unreasonable to suppose that similar conditions in structure must have existed in other species belonging to this family. Therefore, if not otherwise stated, all descriptions and illustrations are based on *Pentremites sulcatus*, *florealis* and *conoideus* for the following reasons: —

1st. These species are found in the most perfect state of preservation.

2nd. They are among the largest species so far discovered.

3rd. They are among the most abundant species to be found here.

I take this opportunity to express my sincere thanks to the following scientific friends for the generous and ready way in which they have facilitated my undertaking by the loan of valuable specimens: Prof. W. H. Barris, of Davenport, Iowa; Mr. R. A. Blair, of Sedalia, Mo.; Dr. J. H. Britts, of Clinton, Mo.; Prof. G. C. Broadhead, of Columbia, Mo.; Mr. G. K. Greene, of New Albany, Ind.; Mr. Edwin G. Kirk, of Burlington, Iowa; Dr. Joshua Lindahl, of Springfield, Ill.; Mr. F. A. Sampson, of Sedalia, Mo.; Mr. C. Schuchert, of the Smithsonian Institution, Washington, D. C.; Prof. A. G. Wetherby, of Cincinnati, Ohio; Dr. W. P. Jenney, and Mess. J. and H. Hurter, of St. Louis, Mo.

It is a well-known fact that all principal parts in the construction of Echinodermata are arranged in multiples of five around a central axis. However, deviations from the prevalent rule occur more frequently in this class of the animal kingdom than elsewhere. Such abnormal developments have often been the cause of redescribing well-known forms as new species, especially among the Crinoideae.* For the purpose of illustrating the tendency of abnormal developments I will give a few examples, which, however, I could have multiplied if time and space would permit. Similar deformities have been observed and described by others.† In Fig. 13 and 14, Plate III., we have a specimen of *Pentremites florealis*, with only four fork pieces and four ambulacra. In Fig. 8 and 9, same plate, *Pentremites pyriformis* has four ambulacra but five fork pieces, of which the fifth is not fully developed. Fig. 15 and 16, same plate, *Pentremites pyriformis*, show six fork pieces but only four ambulacra are fully developed. Fig. 11 and 12, same plate, *Pentremites sulcatus*, show five fork pieces, one of which is a longitudinal square without any sinus, and consequently no ambulacrum has been developed. In Fig. 10, same plate, *Pentremites sulcatus*, we have one ambulacrum developed only to one-half the length of the others. Fig. 6 and 7, same plate, *Pentremites sulcatus*, show an extra longitudinal piece inserted between two fork pieces. Fig. 18, same plate, *Pentremites florealis*, has only four fork pieces but five ambulacra, so that two ambulacra are inserted into one sinus, causing the two opposite halves of the ambulacrum to form a prominent ridge. In Fig. 17, same plate, *Pentremites*

* See Bulletins of the Illinois State Museum of Natural History, by S. A. Miller and W. F. E. Gurley, Nos. 1–12.

† Robert Etheridge, Jun., and P. Herbert Carpenter. Catalogue of the Blastoidea.

Hermann von Meyer. Abweichung von der Fünfzahl bei Echinideen.

Prof. Georg Boehm. Ueber eine Anomalie im Kelche von *Millericrinus mespiliformis*. Zeitschrift der deutschen geologischen Gesellschaft. Band XLIII., Heft 3, p. 741.

H. W. Mackintosh. On a Malformed Corona of *Echinus esculentus*. Proceedings of the Royal Irish Academy. Vol. II., Ser. II., 1875, p. 206.

Dr. Philippi. Beschreibung zweier missgebildeter See-Igel. Wiegmann's Archiv für Naturgeschichte. Band I., 1837, p. 241.

bipyramidalis, Hall (*Saccoblastus*), we have five fork pieces but six ambulacra, of which two occupy one sinus. I think these examples are sufficient to justify the above statement.

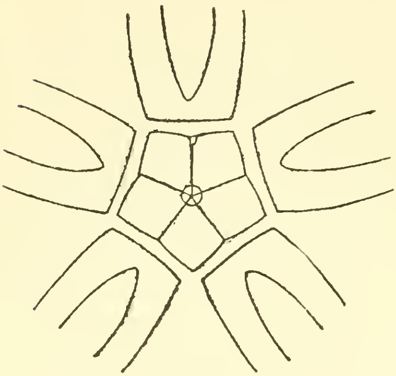


Fig. 1.

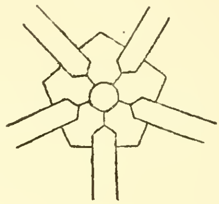


Fig. 2.

The body of a Pentremite is constructed of twenty pieces, (at least in the embryonic state), arranged in two circles in such a way that we have a most perfect dicyclical* body with a primary center of a pentagonal outline for each circle. Each piece of the second circle rests upon two of the first circle. These two circles may be designated as an ambulacral and an interambulacral, of which the former grows downward in its development, whereas the latter grows upward. Fig. 1 and 2.

THE BASAL PIECES.

The base or central part of the interambulacral circle (also called pelvis)† varies very much in size and in general form, from a flat disc to a more or less funnel-shaped piece. It is perforated by a fine channel in the center, and the articulation surface for the column is either round or triangular according to the species and consists, at least in the embryonic state, of five equal pieces, though in the course of development two of the five sutures become obliterated, so that it gener-

* The word dicyclical is not used in the same sense as in Crinoideae.

† H. B. Geinitz. Grundriss der Versteinerungskunde, p. 558.

ally appears as if the base were constructed of only three pieces, of which two are equal and pentagonal and the other rhombic in form, though specimens are frequently found in which no anchylosis took place so that all five sutures remain open, an occurrence which is also observed in Crinoids, for example in *Agassizocrinus* where the base generally appears as one solid piece, though specimens are not uncommon where one, two or all sutures remained open and did not anchylose. Fig. 3.

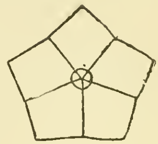


Fig. 3.

FORK PIECES.

The fork pieces are of an oblong form, more or less wide, according to species, and the incision or sinus is also of variable depth and width, making them resemble a two-pronged fork, from which the name originated, or a **V** shape. Their solid base portion is more or less thick and has, in cross section, a more or less triangular or semi-lunar form, or, as in other genera of the family Pentremidae, it is turned in and upward so that the base portion becomes inverted and externally invisible. The incision or sinus is wider externally than internally, *i. e.*, the inner lateral margin of the sinus slopes toward the interior, causing the internal opening of the sinus to be narrower than the external. The upper points of the prongs are cut obliquely laterally making them rest against the upper and lateral spurs of the deltoid expansion. In other species they run out into sharp and acute points as in *Pentremites reinwardtii*, Troost. In still others they are of uniform thickness with an upper oblique and smooth margin.

THE DELTOID PIECES.

The deltoid pieces of the typical species, as *Pentremites sulcatus*, *pyriformis*, *florealis*, etc., when fully developed, can be divided into two parts, which, however, are not separated from each other by sutures. First a main or base portion, the most important part of the whole calyx, which is never wanting; and secondly a laterally expanded blade, not present in the young but becoming gradually more and more developed as they grow older; see Plate VI. The first or base portion, in the typical species above mentioned, has a shape resembling very much a six-sided prism; see Plate II., Fig. 9. The surface toward the center of the calyx has a semi-lunar groove which forms with the adjoining piece the central opening or mouth, and, as this basal part is placed in a slightly oblique position, it causes the external opening to be a little smaller than the internal one. The opposite side of this semi-lunar cavity is prolonged into a narrow blade, except for the posterior one, where the septum is divided into two blades for the outlet of the anus. The lower part is divided lengthwise into two blades, running down and outwards with a plicated outer margin,—Plate II., Fig. 9,—for the support of the plications of the hydrospiric tubes, whereas the upper part of this blade forms a sharp crest, and the outer one a triangular incision, during the juvenile state, for the reception of the upper points of the fork pieces which rest in this triangular incision. At the base of these lamellar blades we find a semi-lunar groove which forms with a similar one on the base of the lancet piece the genital opening, except in species where the deltoid pieces are perforated, as in *G. norwoodi* and similar forms. The outer or upper surface of the base portion is either rounded or sharp pointed, whereas the lower surface, which expands toward the center of the calyx, is grooved transversely so as to form a circular groove around the mouth on the interior side of the calyx for the reception of the central ring of a water vascular system. This central water ring underlies the basal part of the deltoids and does not penetrate the calcareous shell, sending off five straight branches, one for each ambulacrum, running between the hydrospiric tubes and the lancet piece, but not through the latter; see Plate II., Fig. 8.

The outer half of the prism is transversely perforated by a fine channel, forming in connection with the other parts a pentagonal ring for the reception of the nervous center, giving off five branches, one for each ambulacrum, and running through the center of the lancet piece. From the foregoing we see that the whole center of this system as well as the branches run through the midst of a calcareous substance, and their lumen is so small that they are frequently found to be obliterated. It is therefore hardly possible that these fine channels could have served for anything else than the reception of the nervous system, giving us an analogous arrangement to what we find in our living Asteroidea; see Fig. 4.

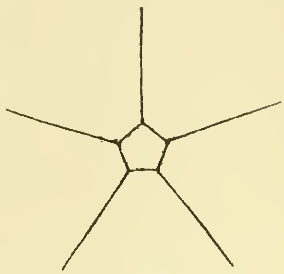


Fig. 4.

The second part, *i. e.*, the lateral expansion in the typical species above mentioned, is not unlike the Greek letter delta, from which the name originated, or resembles an arrow head with a very acute surface upwards and an obtuse one downwards, having on each side a spur, running obliquely down and inwards, so as to be externally concealed by the upper points of the fork pieces. The upper acute surface differs very much in the different species and often in one and the same species, being subject to great variations, so that we find it often very acute and bent inwardly, or very broad and bent outwardly.

In other species, where the calyx consists of only a very thin shell, as for example in *C. melo*, the laminar blade widens immediately so that the whole piece is placed more horizontally on the summit of the calyx, and hardly any division between base portion and lateral expansion takes place, except the incision for the construction of the genital openings, and this same condition can be observed throughout the whole juvenile state of the body. In other species again, as for instance in *C. sayi*, the lateral expansion assumes such an enormous size that it occupies almost three fourths or four fifths of the entire calyx, and in others, as in *G. norwoodi*, the whole deltoid piece has a triangular form and the genital opening pierces directly through the center of this piece, but with only one external opening, bifurcating within the shell, and forming two openings on the interior side. In silicious casts of this species these little openings are often found to be filled with silicious matter, and will naturally show on the summit of such casts a little bifurcating tube, as illustrated by Meek and Worthen,* which undoubtedly gave origin to the supposition that two of the hydrospiric tubes were united near the summit into one, as figured by Billings † and Ludwig.‡ By a little reflection, however, it is easily comprehended that these bifurcating tubes have nothing to do with the hydrospiric tubes and that it is only silicious matter filling out these little channels, for they are never found on casts of other species than those which have the deltoid pieces pierced in the described manner.

From the foregoing it will be seen that we have nearly every degree of development in form and size represented, and this gradual development of the lateral expansion as we find it in the typical specimens of *Pentremites sulcatus*, *pyriformis*, *florealis* and others is a sufficient and good reason to exclude the newly rehabilitated genus *Pentremitidia* of D'Orbigny, whose principal distinguishing character consists in the absence of the lateral expansion, as plainly stated by him: "Calice composé de deux séries de cinq pieux superposées."§ His types for this genus were *Pentremites schultzii* and *paillettei*. But the absence or non-development of the lateral expansion, as it is often found in the typical species, and always in the young specimen of the same species, does not justify the creation of a new genus, as was well remarked by Dr. Roemer: "Gewiss verdient es aber keine Nachahmung."|| Otherwise the young specimens of *Pentremites sulcatus*, *pyriformis*, etc., would belong to the genus *Pentremitidia* during their juvenile state, and afterwards when fully developed to *Pentremites*; see Plate VI., Fig.

* Illinois Geological Survey, Vol. V., plate IX., Fig. 2 c., p. 473.

† Palaeozoic Fossils, Vol. II., Part I., Fig. 60, p. 102.

‡ Morphologische Studien an Echinodermen, Band I., p. 289, Plate 27, Fig. 36 and 37.

§ M. A. D'Orbigny. Prodrome de Paléontologie, Vol. I., p. 102.

|| Roemer. Monographie der fossilien Crinoidenfamilie der Blastoideen, p. 49; and Wiegmann's Archiv für Naturgeschichte, Jahrg. XVII., B. 1.

1–3, because *Pentremites schultzii* and *paillettei* are as typical *Pentremites* as *sulcatus*, *pyriformis* and others, — that is to say, their calyx consists of the same number of pieces with the same relationship of them to each other as in the true *Pentremites*. Their genital openings are constructed by the junction of deltoid and lancet pieces precisely as we find in the typical species above mentioned. Other differences in the character of this genus as lately revised are of no generic value as they are due to the variability in size and shape of basal, fork and lancet pieces, and are only of specific importance.

That the general conception of the deltoid pieces is not a correct one is sufficiently shown by the descriptions given by various authors. They were called interscapular plates, second radials, interradials, orals, etc. The name interradial was first used by DeKoninck at a time when the Blastoideae were regarded as a sub-order of Crinoideae. In 1879 they were regarded as homologous to the oval plates of Crinoids by Wachsmuth, which statement he corrected three or four years later when he called them true interradials.* He says: —

" The term ' oral ' for the deltoid pieces was proposed by Wachsmuth and Springer in Part I. of their Revision, and afterwards adopted by Prof. v. Zittel and by Messrs. Etheridge and Carpenter.

" Since the publication of the present article, I became fully convinced that the so-called deltoid pieces are not oral plates, but true interradials, and that, as such, they form a part of the abactinal system. If the deltoids were actinal plates, and this they should be if they were orals, the actinal regions in *Elaeacrinus obovatus* would extend to over three fourths of the entire body — a proportion almost equal to that of Echini. On the contrary, in the allied *Granatocrinus norwoodi*, with small deltoids, and in *Heteroschisma gracile*, the actinal system excluding the ambulacra, would be limited to a small area around the oral pole, and occupy scarcely more than a twentieth part. The different

* Proceedings Davenport Academy of Natural Sciences, Vol. IV., p. 76.

proportions of the actinal and abactinal regions among Echinoderms were looked upon by Prof. L. Agassiz as determining the different outlines of the various 'orders of this class,' and he has ranked their orders according to the greater preponderance of the one or the other of the two regions. In the Neocrinoidea, the oral and aboral regions are proportioned almost equally, and this is the case not only in the adult, but is to be observed already in the Pentacrinoid-larva. In the Palaeocrinoidea, the abactinal regions, as a rule, are considerably contracted, and in the lower organized Blastoids they are reduced still more. Plates of such enormous dimensions as are found occasionally among the deltoids, cannot possibly form a part of the actinal system in so low a group as the Blastoids, and hence cannot be orals. That they are true interradials is proved by the relative position which they occupy to the interradials of the Palaeocrinoideae. Like those plates, they rest upon the upper sloping sides of the radials, and extend, whether consisting of a single plate as in the Cyathocrinidae, or of a series of pieces as in Actinocrinidae and Rhodocrinidae, into the ventral side, to a series of plates, which were designated by W. and Sp. as central pieces and proximals.''

The first question which presents itself is, what is meant by interradial? The word undoubtedly means something between the rays of a circle. We therefore have to assume a primary circle of rays or plates between which the secondary parts can be placed, as, for example, in Crinoids those plates which are placed between the regular radial plates. The second question would be, what is the function of the interradials? Referring to Crinoids again we find that their function is to fill out space in order to increase the circumference of the body. They are not essential to the construction of the body or calyx as is well illustrated in a number of Crinoids which have no interradials. Besides, their number is variable. Therefore they may be regarded as supernumerary pieces whose only function is to enlarge the body. In no case do they enter into the construction of the various openings unless we regard the anals as interradials, which I think has not been done so far. But in the case under consideration, that is in *Pentremites* and allied forms, the body is dicyclical, which it could not be if the deltoids were interradial. In that case the apex of the deltoid, *i. e.*, the lateral expansion, would be the base and not the apex and hence would have been developed first, which is not the case as I have shown above,—Plate VI., Fig. 1–3. However large or small the lateral expansion of the deltoid may be, the fact is that the base part of the deltoid is developed first and is the principal part of the body. It is not separated from the laterally expanded part by any suture. All principal openings are constructed by this part, or together with the lancet piece, or the openings pierce the deltoid piece. They do not rest upon the upper sloping sides of the fork pieces or radials but the fork pieces lean against the deltoid piece whether the laterally expanded part is developed or not. Therefore it is hardly possible to assume that such important pieces as the deltoids should have been developed later than less important ones, which is sufficiently demonstrated by the foregoing pages. For these reasons they cannot be interradials.

LANCET PIECES.

The lancet piece varies very much according to the dimensions of the fork piece sinus, *i. e.*, according to the species, from a regular lancet-shaped piece to a mere linear lamella and fits in the sinus of the fork piece in such a way as to fill the incision with the exception of a narrow fissure on each side. They are in the typical forms, as *Pentremites sulcatus*, *P. florealis*, *P. pyriformis*, etc., as substantial as the other parts of the calyx and form an integral part of the calyx of the same value as the other pieces constructing it, and are in large specimens of *P. sulcatus* fully one eighth inch thick. They are generally of uniform width with a smooth anterior surface, whereas the posterior or inner surface is more or less concave and has a semi-lunar groove throughout its length for the reception of some duct or vessel. On the upper or base portion is a little beak-like process of a triangular form by which it connects with the *annulus centralis* or central ring of the deltoid pieces, resting thereby on two deltoid pieces; see Fig. 2. The center of these pieces is perforated by a fine channel in its entire length, bifurcating at its base to connect with the transverse channel of the deltoid base-portion, forming thus a pentagonal ring around the central opening. The size of these channels is such that it seems hardly possible that they could serve for the water vascular system. It seems more probable that they contained the nervous system, giving a similar arrangement to what we find in higher forms like Asteroids; see Fig. 4.

The little beak-like process where the lancet piece connects with the deltoid is laterally grooved to form with the corresponding groove of the deltoid, the ovarian or genital aperture except in species where the deltoid piece is perforated, as in *G. norwoodi*.

PORAL PIECES.

The triangular groove which is formed by the outer margin of the lancet piece and the inner margin of the fork piece sinus is filled with little pieces corresponding to this groove, which were called most appropriately poral pieces by Dr. Roemer. This name has been changed to side plates by R. Etheridge, Jr., and P. H. Carpenter,* which term is also adopted by C. R. Eastman.† The reason given for the change of this name is not a logical one and shows that the nature of the pieces is not thoroughly comprehended. Are perhaps the poral openings not constructed by the poral pieces? Does not the name poral piece indicate the nature better than the new name? What benefit is to be derived from the new name? They are of a triangular form, corresponding to the groove which they occupy. They are inserted edgewise so that the thickness of these pieces forms their outer exposed surface; see Fig. 5. These pieces have on both sides of their outer lateral margin a little semi-lunar groove, which with the adjoining one forms the pore-opening, and, in no case, are these pieces

* Catalogue of the Blastoidea.

† Text Book of Palaeontology.

pierced by marginal pores, as stated by C. R. Eastman.* They are supernumerary pieces and form a kind of accessory part to the construction of the ambulacrum. It is self-evident that there are differences in the size and shape of these pieces, depending upon the size and shape of the lancet piece as well as upon the fork piece sinus; but all have undoubtedly the same physiological function, so that such difference in the size and shape can be of specific value only.

THE AMBULACRAL INTEGUMENT.

The outer surface of the ambulacrum, *i. e.*, the lancet and poral pieces, is covered by an organic and elastic integument which I formerly designated as the zigzag plicated integument.† It gives to the ambulacral surface a striated appearance which is not, as Etheridge and Carpenter state, "merely a delicate surface ornamentation." ‡ This integument has a different appearance in different species, and varies very much in its zigzag shape and in the distance of its windings. In most cases it is so eroded that it is almost impossible to make out its true appearance. It may be regarded as a ribbon placed obliquely on edge and running in a zigzag form forward and back so that the lower opposite edges of the returning ribbon unite and form the bottom of a little groove, while the other or upper edges form a little ridge; see Plate II., Fig. 2 and 5. These ridges show an open surface in species like *Pentremites pyriformis* and *florealis*, whereas in *Pentremites sulcatus* and others they are firmly united to the margin of the poral pieces. There is also a great variety in the distance between two ridges. In *Pentremites pyriformis* we may count nine to $\frac{1}{8}$ inch, whereas in *Pentremites sulcatus* we have eleven to $\frac{1}{8}$ inch, etc. It begins with an acute point at the center of the deltoids, surrounding two ovarian or genital openings, and does this in typical species like *Pentremites sulcatus*, *florealis*, *pyriformis*, etc., in such a way as to make the two openings appear as one, externally. In some species, as *C. sayi*, the

* Text Book of Palaeontology, p. 192.

† Transactions St. Louis Academy of Science, Vol. IV., p. 150.

‡ Catalogue of the Blastoidea, p. 59.

integument does not run close to the margin of the sinus in the vicinity of the ovarian or genital openings, making them appear as little slits instead of round openings. It runs in the shape of a letter Λ inverted with the two arms extending out and downward to the apex of the ambulacrum. Each

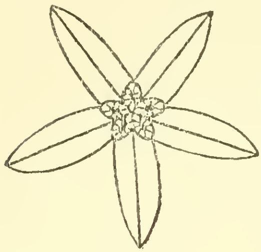


Fig. 5.

arm covers one-half of the ambulacral surface, forming with the opposite one a longitudinal groove in the center (the so-called foot groove). This foot groove and the little transverse grooves at each side of it are covered with little scales, so that, in specimens very well preserved, the ambulacrum does not show any transversely striated surface at all, but appears rather smooth or granulated with a little crest in the center. The whole covering is of a uniform character, except on the summit, where the scales surrounding the ovarian or genital apertures (at least in the typical species) are fully ten times as long and placed erect on the underlying membrane,—see Fig. 5 and Plate II., Fig. 2, 3, 5,—forming in this way a part of the cone-shaped body which has been observed on the summit of many species. Their physiological function is still unknown, but probably it was to protect the finer inner ovarian tubes. Besides the scales we find on the posterior side above the anal opening, on very well preserved specimens, a small proboscis about one fourth of an inch in length, constructed of small hexagonal pieces, as shown in Fig. 6 and 7. To my knowledge it is the first time that such a body has been observed on a Blastoid. I found this appendix on *Pentremites conoideus*

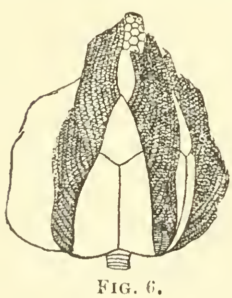


Fig. 6.

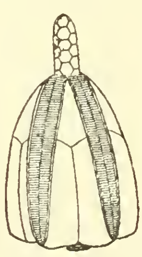


Fig. 7.

and have now four specimens of it showing this, so far unknown, organ. All four specimens are in an excellent state of preservation and show also the pinnulae preserved. I am inclined to believe that similar organs existed in all typical species. At the outer margin of the ambulacrum, where the outward running ribbon returns to the center of the field, the ribbon is twisted over so that the fold facilitating the return is the under surface of the ribbon and becomes the articulation surface of the pinnulae; see Plate II., Fig. 5. These pinnulae are little filaments of various lengths extending in some species as much beyond the summit as the entire length of the calyx, or even more. They consist of a single row of calcareous particles, wedge-shaped in form and about as broad as long.

As evidence to support the foregoing assertion, *i. e.*, the flexibility and organic nature of the ambulacral integument, I give in Figures 1–7, Plate I., representations of some pathologic specimens selected from a large amount of material collected for this purpose. I have over fifty such pathologic specimens, showing various kinds of injuries and the subsequent restoration of the injured parts, which would have been impossible had the integument been inorganic matter only, as supposed by Carpenter. All specimens figured, belong to the species *Pentremites sulcatus*. Plate I., Fig. 6, shows an injury near the middle of the ambulacrum; Fig. 5 a similar injury on one side of the field and on the other side the loss of half the poral pieces and the subsequent restoration of the integument. Fig. 1 and 2 show the flexion of the transverse ridges into a sigmoid form and the partly compressed shape of the genital openings; Fig. 7 and Plate II., Fig. 7 show the unevenness of the integument at the outer margin near the sinus.

The acute points at the beginning of the ambulacral integument are the only covering for the central orifice. (The surrounding genital openings are entirely out of the question.) The different descriptions and illustrations given (which all differ from each other) are erroneous representations due to mistaking foreign matter for covering plates, as already expressed in my first paper.* Nothing is more natural than that some of the little scales or particles of broken pinnulae should drop into some of the summit openings and

* Transactions of The St. Louis Academy of Science, Vol. IV., p. 150.

remain there, which also accounts for the irregularity of these coverings as described and figured by the different authors. It is strange that every one adheres to the old idea of Shumard, and that no one has taken the pains to examine the matter more carefully in order to convince himself of the true nature of it. This irregular arrangement of the pieces covering the summit openings, as described by Eastman,* is evidence for the contradiction of his statement, because it is hard to suppose that specimens belonging to one and the same species should not have a uniform arrangement in the covering plates of their openings if such a covering existed.

It is true that Wachsmuth admits, after seeing Shumard's type specimen of *Pentremites conoideus* that the summit openings are not closed in the manner described by Shumard but he still believes that they are closed.

It stands to reason and is only logical to suppose that, if nature provided an opening it should remain open or that the covering is a flexible one and not formed by additional plates inserted into the openings as intimated by all authors who adopted the first statement of Shumard. No one explains or gives any reason why the opening should be closed. Every one disregards the fact that all casts of the interior of a calyx exhibit on the summit a cast of the summit opening, which could not be possible if the openings had been closed by additional pieces. This fact has not been observed on specimens of *Olivanites* or others where the center of the summit is closed.

THE WATER VASCULAR SYSTEM.

On the under side of the lancet piece and completely filling the semi-lunar groove we find a tubular vessel connecting with a circular ring underlying the base of the deltoid and surrounding the central orifice. The thickness of this vascular ring and its branches varies according to the species. The diameter of this vessel is about 1-20 of an inch in a large specimen of *Pentremites sulcatus.*

* Text Book of Palaeontology, Vol. I., p. 197.

It is not often found preserved, at least not in an open condition, but oftener in a collapsed condition. In this condition it presents the so-called underlancet plate of late authors.* I can prove the existence of this vessel by a number of cross sections of an ambulacrum of which Fig. 8 and Plate II. are a correct representation. Lancet piece and poral pieces are well preserved, also the vascular duct *a*, which in this specimen is filled with calcspar which could enter only in a liquid state. The triangular space *b* at each side of the vessel is filled by a kind of clayey substance, which must also have been in a very plastic or liquid form when entering the cavity. Underneath we have the hydrospiric plications *c*. Had the vessel *a* not existed the substance in *b* would have undoubtedly filled the whole space if it were the first to enter the calyx. On the other hand if the liquid calcspar had entered first it would have spread over the whole space if no vessel had existed. The walls of these vessels must have been very thin, which accounts for their easy destruction and absence in most cases. In an empty state they would naturally have collapsed, but nevertheless could easily be distinguished from the underlying upper blade of the hydrospiric tube, in not showing a suture line in the center, which would be the case if the vessel had been destroyed and the upper blade of the hydrospiric tube were exposed to view.

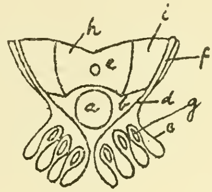


FIG. 8.

a. Water vascular duct.
b. Space at each side of duct filled with clayey substance.
c. Lobes of the hydrospiric tube.
d. Upper blade of the hydrospiric tube.
e. Nervous channel.
f. Tentacle.
g. Ovarian tubes.
h. Lancet plate.
i. Poral pieces.

THE HYDROSPIRES OR RESPIRATORY ORGAN.

The hydrospires in the typical species like *Pentremites sulcatus*, *florealis*, *pyriformis*, etc., form ten isolated plicated

* Eastman. Text Book of Palaeontology, Vol. I., p. 191.

membranous tubes and not bundles of tubes as stated by various authors, and accompanied by incorrect illustrations. They are located beneath the water duct and run parallel to it from near the summit of the calyx to the apex of the ambulacrum. The plications rest in little grooves of the expanded lower deltoid portion, and are not united with the adjoining one to form five bundles as described and illustrated by Billings * and Ludwig.† These plicated tubes or hydrospires are of a peculiar construction. Each tube may be regarded as a somewhat collapsed cylinder of which the upper blade, *i. e.*, the one nearest to the water duct, is smooth in its whole length, whereas the underlying blade is folded into a number of plications of no regularity. They vary in number

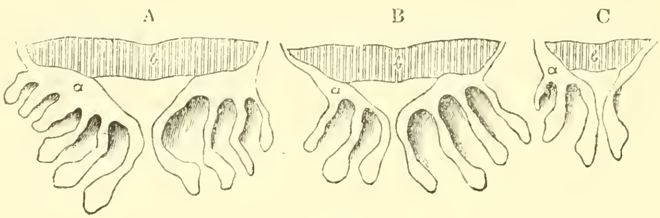


FIG. 9.

TRANSVERSE SECTIONS OF AMBULACRAL FIELDS, to show abnormal developments of the hydrospiric sacs: A, of *Pentremites pyriformis;* B, *P. florealis;* C, *P. conoideus* — about 20 times magnified and drawn with the aid of the camera lucida. *a*, hydrospiric sac; *b*, calcareous part of ambulacral field, *i. e.* lancet and poral pieces.

in the different species and vary very often in one and the same specimen; see Fig. 9. At the outer margin where these two blades meet, that is, where the upper smooth blade connects with the lower plicated one, they run out into little thread-like filaments or tentacles, giving the compressed cylinder a fringed appearance on this side. They form the so much doubted tentacles which protrude through the poral openings and form

* Palaeozoic Fossils, Vol. II., Part 1, p. 102.

† H. Ludwig. Morphologische Studien an Echinodermen, Band I., p. 289. Taf. XXVII., Fig. 36, 37.

in their collapsed state the supplementary poral pieces of Dr. Roemer * or outer side plates of later authors.†

What could be the function of these supplementary poral pieces situated as described by Dr. Roemer, within the poral opening? As I understand the term it applies to something similar to and in addition to the poral piece, that is a small piece inserted in the poral opening. According to the Doctor's description it served to reduce the opening, which, however, is not a very plausible supposition, as the same result might have been accomplished by nature in a much simpler manner by lessening the groove in the pore piece. Therefore I deem it proper to seek for another explanation which is to be found in supposing them to be tentacles. The correctness of this supposition is easily tested, as there can be only three possible conditions: —

1st. If a supplementary poral piece existed it should be found by making a transverse section through or near the middle of a pore channel, say at the line indicated from *a* to *b* in Fig. 10.

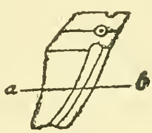


FIG. 10.

2d. If then the supplementary poral pieces are not preserved, we should find the poral opening vacant or filled with foreign matter.

3d. If my supposition is correct and the tentacles are preserved, we will find them by making such a section, in either an open or collapsed condition. In a number of sections I have made I can prove the existence of the so much doubted tentacles in either condition. Fig. 1, Plate II., is a transverse section through a row of poral pieces of *Pentremites florealis*, showing the preservation of the tentacles in a some what collapsed condition. Fig. 4 is a similar section of *Pentremites abbreviatus* showing the tentacles in an open condition. I could show further evidence of their existence in pathologic specimens where mechanical injuries had been inflicted, causing a hypertrophic growth of some of the tentacles into a little bundle of tubes.

The plications, as already stated, vary in number and in the

* Wiegmann's Archiv für Naturgeschichte, Jahrg. XVII., Bd. I., p. 335.
† Eastman. Text Book of Palaeontology, Vol. I., p. 191.

manner of folding. They are in an end view not unlike an unsymmetrical figure 8,—see Fig. 11,—of which the upper loop is larger than the lower one. These loops, in large specimens of *Pentremites sulcatus*, are one fourth of an inch long. Counting five folds to each of the ten cylinders, or ten to each ambulacrum, it would give for the whole body, if stretched out, a ribbon over two feet long — an organ well adapted for respiratory function as supposed by Billings.* The apices of these foldings are often found to have coalesced with the calcareous base part of the fork pieces as observed in *Pentremites conoideus* and others, whereas the plicae of the other end rest in those plications or grooves of the deltoid expansion already described near the summit openings. The coalescing with the calcareous base portion of the fork pieces is not a peculiarity found only in certain species as indicated by Carpenter,† but it can be observed in other species, as in *Pentremites florealis*, etc. Between the upper loops of these plications, which are kept open by resting in the little grooves near the summit, we find longitudinal tubes, protruding through the genital openings on the summit and filling them completely. These tubes I regard as the ovarian or genital tubes. They are found (in well preserved specimens) to be filled with little round bodies (eggs?). Fig. 6, Plate II., is a longitudinal section through the upper loop of a hydrospiric cylinder of *Pentremites florealis*, exhibiting these little round bodies at various places. The supposition that these are ovarian tubes is strengthened by the fact that the plications near the summit rest in grooves, which would be necessary to prevent any obstruction to the passage of the egg.

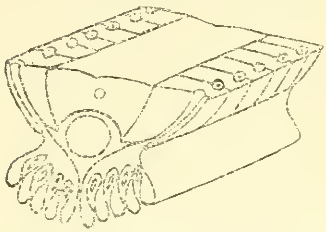


Fig. 11.

In *Codaster* the construction of the hydrospires is quite different. Here we have from the roof of the calyx vertical lamellae one eighth to one fourth of an inch long, reaching

* Billings, *Loc. cit.*, p. 103.

† Carpenter, *Loc. cit.*

into the interior of the calyx and varying in number according to species from six to twelve or even more. These lamellae are completely surrounded by a ribbon-like membrane; see Plate II., Fig. 11. The water is admitted to the surface of the membrane by longitudinal slits in the calcareous substance of the roof between the vertical lamellae. Whether these slits were covered or not I am unable to say on account of the insufficiency of material for study.

EARLIER CLASSIFICATION.

As already remarked, the present classification is largely based on external resemblances and is a very arbitrary one, lacking a good foundation of morphologic as well as ontogenetic characters, in consequence of which it becomes inadequate. This induces me to offer a new classification based on determinative and permanent anatomical differences as well as ontogenetic peculiarities. If the Blastoideae form an independent class like the Crinoideae or Cystoideae, which I believe is now generally admitted, then in revising the present classification all names that have an ending "crinus" ought to be canceled and new and proper ones substituted for them. This was already recommended by Quenstedt in 1876.* If this had been done it would have avoided the confusion resulting from the retention of improper names and from referring species to genera to which they do not belong, especially when the author is doubtful about their propriety, which is always indicated by a question mark, or from substituting new names for parts of the body which are not as significant as the old ones.

The ontogeny of extinct families can only be studied with a large amount of material from one and the same locality, which will enable us to make comparisons between the young and adult specimens, to ascertain if all parts are keeping step in the progress of development, or if one part has developed more rapidly than the others, and in which direction this development has taken place.

For the purpose of proving the arbitrary condition I will review the genus *Granatocrinus* and for the convenience of

* F. A. Quenstedt. Petrefactenkunde Deutschlands, Vierter Band., p. 719.

the reader, I will recapitulate the various views of our most distinguished palaeontologists concerning this question, which will show that very little attention was given to anatomical differences, and that all specimens enumerated in this genus were placed there on merely external resemblances. If anatomical differences had been considered, Shumard would never have proposed to put species like *Granatocrinus norwoodi*, *curtus*, *granulatus*, *sayi*, *roemeri*, *cornutus*, etc., into one genus*

In 1861, Meek and Worthen say, in speaking about *Pentremites cornutus* and *Pentremites melo:*† "Both of these forms differ from the typical species of the genus *Pentremites* in having each pair of ovarian openings distinctly separated, instead of closely united with merely a thin septum between. In this character, as well as in form, and the prolongation of the pseudo-ambulacral areas, they agree with the genus *Nucleocrinus* of Conrad (= *Elaeacrinus*, Roemer), from which they differ in having the anal and oral openings distinct as in the true *Pentremites.* They constitute a subgenus of *Pentremites*, occupying a position between the typical forms of that genus and *Nucleocrinus.*"

In 1862 Prof. Hall says in speaking about the genus *Nucleocrinus:* ‡ —

"Regarding only the general form of these bodies, this genus would include several species, heretofore described under *Pentremites*, from the Carboniferous limestones of the Western States, viz.: *Pentremites norwoodi*, Owen and Shumard: *Pentremites melo*, Owen and Shumard; *Pentremites curtus*, Shumard, and others; while the *Pentremites* (*Olivanites*) *verneuili* = *Elaeacrinus verneuili*, Roemer, and *Olivanites angularis*, Lyon, are of the age of the upper Helderberg limestones; and the *Nucleocrinus elegans*, Conrad, and at least one other species, occur in the Hamilton group. The

* Roemer's *Pentremites granulatus* is taken as type of the genus. — See B. F. Shumard, Transactions of The Academy of Science of St. Louis, Vol. II., p. 375.

† Proceedings of The Academy of Natural Sciences of Philadelphia, 1861, p. 142.

‡ Fifteenth Annual Report of the Regents of the University of the State of New York, p. 145.

Pentremites roemeri, Shumard, is referred to the Chemung group.

"Looking at other characters than those of general form, the specimens before me scarcely warrant the union of all these species under the genus *Nucleocrinus* or *Elaeacrinus*. In *Nucleocrinus elegans*, and allied forms, we have three small basal plates and five short radials, which embrace the base of the pseudambulacral fields; while the interradial plates are extremely large, extending nearly the whole length of the pseudambulacral areas. The anal side is often, or usually, flattened, a little broader than the others, and is marked by a narrow lanceolate plate, which extends from the opening to the summit of the radial plates, resting upon them; thus, as it were, dividing the interradial plate, leaving a narrow portion on each side adjacent to the pseudambulacral fields. The central area at the summit, between the ovarian openings, is occupied by several small plates, which, in *Nucleocrinus elegans*, converge to the center.

"In the structure of the body, the typical forms of this genus differ from *Pentremites* in the short radial plates and extremely elongated interradials, which fill nearly all the space between the pseudambulacral areas; while the elongate anal plate is a marked feature. Now when we compare *Pentremites norwoodi* and *Pentremites melo*, we have the same general form of body, with the extremely elongate, instead of the short, radial or forked plates which embrace the pseudambulacral fields; and a small interradial at the summit. The ovarian apertures, as well as perhaps the central opening, sometimes preserve minute plates, which close these orifices. The form alone can scarcely be of generic importance; for, although the base of *Nucleocrinus* is usually concave, I have before me a species where the base is not concave, and the three basal plates are quite prominent. The only conspicuous difference between *Pentremites norwoodi* and *Pentremites godoni* and others of the latter form, is in the depressed base and greater rotundity of the former species, giving to it its similarity to *Nucleocrinus*. The *Pentremites norwoodi* and *Pentremites melo* have not the anal side conspicuously wider, more prominent, or flattened; which is the character observed in all true *Nucleocrini*.

"The different arrangement of parts, also, in the two genera, causes a different mode of increase in the plates, and a different surface-character.

"There is likewise an intermediate form represented by the *Granatocrinus* of Troost (*Pentremites granulatus?* of Roemer). This species is elliptical in form, with depressed base embracing in the bottom of the cavity the three small basal plates, while the radial plates reach halfway up the sides of the body. The anal side is not conspicuously different from the others, and the summit is unlike *Nucleocrinus;* while it is more nearly like *Pentremites norwoodi*. This species is strongly granulose or tuberculose. The *Pentremites sayi* appears to me to belong to the same type; its base is not depressed, leaving the three basal plates protruding; while the radial plates reach about one-third the entire length, in this respect approaching *Nucleocrinus*. In both these species the plate on the anal side occupies the entire space between the pseudambulacral fields, presenting scarcely any important difference from the other interambulacral or interradial spaces.

"I would therefore suggest the separation of the species under the name originally given by Dr. Troost, viz., *Granatocrinus*."

In 1863 Dr. Shumard's remarks regarding the genus *Elaeacrinus* are as follows: * —

"There is, in my opinion, good grounds for separating from the genus *Pentremites* those forms that have been hitherto included in the group *Elliptici* of Prof. Roemer, and placing them in the genus *Elaeacrinus* of the same author. We therefore propose now to group in the latter genus such forms as *Pentremites melo*, *Pentremites norwoodi*, *P. curtus*, *P. granulatus*, *P. roemeri*, *P. sayi*, *P. cornutus*, and the species we are about to describe; also the *Nucleocrinus angularis* of Lyon. Among European species, the following may be

---

* Transactions St. Louis Academy, Vol. II., p. 111.

grouped in this genus: *Pentremites ellipticus*, *P. orbicularis*, *P. derbiensis*, *P. oblongus*, and *P. angulatus*.

"These form a very natural group, easily recognizable, and distinguished from the typical species of *Pentremites* by well marked characters. They are always of an elliptical or sub-globular shape. The pseudo-ambulacral areas are narrow, with sides subparallel, and extend usually the entire length of the body. The basal pieces are nearly always concave, and generally situated at the bottom of a deep excavation. The tubular lamellae, which in the interior reach from the ovarial apertures to the base of the pseudo-ambulacral fields, are more simple in structure, being much less convoluted, while the relative position of the ovarial apertures is different.

"The typical species of the genus *Elaeacrinus*, viz., *Elaeacrinus verneuili*, long previous to the publication of Prof. Roemer's description with figures was well known to American and also to some European palaeontologists as *Olivanites verneuili*, under which name it was designated by Prof. G. Troost in his Monograph on North American Crinoidea, which valuable memoir was completed a short time previous to the death of its author, but is not yet published. According therefore to the laws of priority, Roemer's name, *Elaeacrinus*, proposed in 1852, must be adopted, although it is to be regretted that the learned author did not adopt Troost's generic name in preference to creating a new one.

"It is possible that the genus *Nucleocrinus*, proposed by Conrad in 1842 (Jour. Acad. Nat. Sci., Philad., Vol. VIII., p. 280, Pl. XV., Fig. 17), may be identical with *Elaeacrinus*; but the meager and unsatisfactory description of Conrad ('this genus differs from *Pentremites*, Say, in having only one perforation at top, which is central') does not apply to any of the forms we propose to group in *Elaeacrinus*."

In 1866 Dr. Shumard adopts the suggestion of Prof. Hall. He says:* —

"Adopting the suggestion of Prof. Hall, I here include under *Granatocrinus* (genus proposed by the late Dr. Troost),

* Transact., Vol. II., p. 375.

a number of elliptical Blastoideans which have hitherto been grouped with *Pentremites* and *Elaeacrinus*. The *Granatocrinus* (*Pentatrematites*) *granulatus*, Roemer = *Granatocrinus cidariformis*, Troost, may be regarded as the type of the genus, and for the present it may be extended so as to include such species as *Pentremites melo* and *Pentremites norwoodi*, Owen and Shumard, and allied forms, though it may become necessary after a while to remove these from *Granatocrinus* and group them in a separate subsection under another name. They differ from *Elaeacrinus* in having elongate radial plates, extending, in some instances, almost the entire length of the pseudambulacral fields, while the interradials are in most instances extremely short. The structure of the summit is also quite different; the anal field is not flattened and conspicuously wider than the others, and it is not provided with a supplementary lanceolate piece as we find in *Elaeacrinus* proper."

In the same year, 1866, F. B. Meek and Prof. Worthen give us a description of the genus *Granatocrinus*,* which is as follows: —

"The generic formula of this group is exactly the same as that of *Pentremites*, Say, so far as regards the number and arrangement of the pieces forming the body, though the form and proportions of these pieces are so different as to give a very different outline and general physiognomy to the entire fossil. They are therefore readily distinguished from Say's genus, as properly restricted, by their regular oval, elliptical, or subglobose form, concave or less protuberant base, and much narrower and more elongated pseudo-ambulacral areas, which extend the entire length of the body, so as to give it more the appearance of an Echinoid. They likewise present differences in the arrangement of the ovarian ? openings of the summit, which are more intimately connected with the interradial pieces, being sometimes excavated, one into each lateral margin of these pieces (*G. sayi*); or in other instances piercing directly through them, so that each pair appears

* Meek and Worthen. Geological Survey of Illinois, Vol. II., p. 274.

externally, as a single opening (*G. melo* * and *G. norwoodi*), though they divide into two distinct canals before passing entirely through the plates. The typical forms of this genus also have the interradial pieces proportionally much larger than in the true *Pentremites*,† though this is not a constant character.

"In the possession of numerous, extremely slender, thread-like, simple arms, arranged along the pseudo-ambulacral areas, this type also agrees (as might have been inferred from analogy) with the true *Pentremites*, as we know from the examination of a beautiful specimen belonging to Mr. Wachsmuth. This specimen seems to be related to *G. norwoodi*, as near as can be determined, and shows at least thirty (there are probably more) of these delicate, simple arms, arising from each pseudo-ambulacral area, and extending up so that the lower ones must be quite twice as long as the body. They are all composed of equal joints, about as long as wide. So far as we know, this is the only example of a specimen of this type showing the arms, yet found.

"As now understood, this genus includes species differing materially in the comparative size of the interradial pieces, the typical species having those pieces very large;‡ while in another section of the genus, represented by such forms as *G. melo* and *G. norwoodi*, they are as small as in *Pentremites*. There are so many gradations in this character, however, that it does not seem to be possible to make it a means of separating the species into two well defined sections."

The first one to use the name *Granatocrinus* was Dr. Troost in a list of new species of Crinoideae from Tennessee, which was read by Prof. L. Agassiz at the meeting of the A. A. A. S. in 1850, and published in the Proceedings of Amer. Assoc., Cambridge Meeting, p. 62, but, as a description of the different species was never furnished, these names

---

* *Loc. cit.* 274. Here no difference is made between the summit construction of *G. melo* and *G. norwoodi*.

† Meek and Worthen. Geological Survey of Illinois, Vol. II., p. 275.

‡ Referring evidently to the original species of Dr. Troost, *G. cidariformis* Meek and Worthen, Geological Survey of Illinois, Vol. II., p. 275.

are of no value and have no right to claim priority. The species which Dr. Troost had designated by this name was first described by Dr. Roemer in 1851 * under the name of *Pentatrematites granulatus*, to which Dr. Roemer remarks that he had retained the specific name found on the label of Troost's specimen in the Doctor's collection. However, this name does not appear in Troost's list, but I can state with permission of the Smithsonian Institution, which is now in possession of the Troost collection, that the collection contains specimens labeled by Dr. Troost as *Granatocrinus granularis*, as is to be seen from the following list: —

	Troost's number.	Number of Smithsonian Institution.
Granatocrinus granularis (cast)	1993	33087
G. cidariformis, 2 specimens	2839	33080
G. granularis, 2 specimens (casts)	2788	33097
G. globosus, 2 sp., one a cast and one silicified	2788½	33077
G. —— (nov.) (cast) 10 miles north of Huntsville, Ala		33089
G. —— (cast) Fayetteville, N. C		11476

The last two are like the specimens in the Troost collection, but do not belong to it.

All these specimens seem to be one and the same species, with the only difference that *granularis* is a little smaller than *cidariformis*. Most of them are silicious casts and not in a good state of preservation. With permission of the Smithsonian Institution I will give the Doctor's description, copied from his manuscript together with a figure of both specimens. This description is very deficient as some of the most essential parts have been omitted or misrepresented. The one labeled *granularis* is a little smaller and deformed but shows the articulation surface of the column, and indications of genital openings, which are very small for the size of the specimen, but in none of the specimens is the deltoid piece perforated as we find it in *G. norwoodi*.

---

* Wiegmann's Archiv für Naturgeschichte, 1851, p. 363.

" GRANATOCRINITES mihi, new genus.

" This genus in some of its characters approaches *Olivanites* and *Pentremites*, having like these genera five double rows of pores. It is distinguished from the *Pentremites* by the absence of a column,* and by being destitute of the five characteristic apertures upon which the generic name of *Pentremites* is founded, and from the *Olivanites* by the division of the fields between the ambulacrals which in the *Granatocrinites* is composed of three plates and which is not the case with the *Olivanites*.

" GRANATOCRINITES CIDARIFORMIS mihi.

Pl. III., Fig. 1, 2, 3.

" Globular slightly elongated.

" Pelvis more or less stellated or pentagonal, composed of small plates, forming a small concave dome without any marks of insertion of a column or of an appearance of an alimentary aperture. The five plates which surround the pelvis are elongated sub-pentagonal approaching in form similar plates in the *Pentremites*, their superior margin being circular and having a longitudinal incision which terminates near the base, where they form the margin of the pelvic cavity and thence rising they enclose partly the double rows of pores which descend from the summit and terminate near the lower margin.

" These five plates combined form a cup with five circular elevations at the rim, re-entering angles of which are placed five isosceles triangular plates being beveled at the base so as to fit the rounded margin of the inferior plates.†

" Five double rows of pores proceed from the very summit, running along the triangular plates above mentioned and

* This I must contradict, as the Doctor certainly has overlooked altogether the very plainly marked articulation surface of the column to be seen on his specimen.

† Footnote: As given in Troost MSS.

entering into the incision of lower series of plates first mentioned terminate near the lower margin of them. The whole surface is granulated; these grains have a tendency to run parallel to the sides of the plates.*

"No ovary or oral aperture is visible on the surface; they may nevertheless have existed in the live state, and have been obliterated during fossilification, because judging from siliceous internal casts of the same I think I perceive traces of such apertures. They occur near Shelbyville, Bedford Co., Devonian, and in Allen County, Ky.

"GRANATOCRINITES GLOBOSUS mihi.

Pl. III., Fig. 4.

"It differs from *G. cidariformis* in being globular, having at the base a circular cavity, the junction of the lower series of plates with those of the superior being curvilinear, and the surface being very irregularly granulated, whereas the *G. cidariformis* is oval, has a pentagonal basal cavity, the junction of the above mentioned place is rectilinear and its surface regularly granulated. Bedford County, Tennessee."

To judge from this insufficient description it is not unreasonable to suppose that as the Doctor received more material, he changed the name without removing the label *granularis*, regarding both as the same species, otherwise I should think he would have inserted this name in his list. Although this species is a very rare one it was well known to our most distinguished palaeontologists, for Dr. Shumard possessed specimens of it in his collection. It is also represented in Doctor Yandell's collection, and in the catalogue of Worthen's collection offered for sale in 1889, we find under number 66 two specimens named by Worthen, *Granatocrinus granulosus*, Roemer, from Maury County, Tennessee.

These two specimens are now in the Illinois State Collection with the same label under number 10066, and one of

* This is an incorrect statement, because the specimen shows just the reverse.

the specimens shows remarkably well the genital openings, ten in number, but no perforation of the deltoid piece as we find in *G. norwoodi*. From the foregoing it will be seen that our most distinguished palaeontologists, Hall, Shumard, Meek, Worthen, and others were very well acquainted with *Pentremites granulatus* Roemer = *Granatocrinus cidariformis* Troost, but from all appearance, they bestowed very little attention upon the morphological conditions of this species. Their main object for consideration seems to have been the general form and appearance. If this had not been the case, one can hardly perceive how Shumard, Hall, Meek and others could have grouped species together in such a way as they have done. If it was necessary to remove *Pentremites norwoodi* from the true genus *Pentremites* on account of its difference in structure, it was equally necessary to separate it from Troost's *Granatocrinus* because *Pentremites norwoodi* differs as much from one as from the other.

The same uncertainty is manifested in all the later classifications as will be seen from the following abstracts: Zittel, Handbuch der Palaeontologie, Band I., p. 434, gives it as follows: —

"Gattung, Granatocrinus Troost. Elliptisch, eiförmig oder kugelich. Kelch wie bei voriger Gattung zusammengesetzt, aber B. [Basalstücke] klein, eingesenkt, seitlich nicht sichtbar. Gabelstücke verhältnissmässig klein, etwa zur halben Höhe reichend. Deltoidstücke gross. Psuedoambulacralfelder schmal, linear, bis zur Basis des Körpers herablaufend. Kohlenkalk. *Gr. ellipticus*, *norwoodi*, etc."

But one of the type specimens shows just the reverse, *i. e.*, *G. norwoodi*. We see here that the most characteristic part, *i. e.*, the nature and construction of the genital openings, is not considered, whereas great stress is laid upon all features of a more general character.

Hoerne's definition, Elemente der Palaeontologie, p. 128, is:—

"Granatocrinus Troost. Kelch wie bei *Pentremites* zusammengesetzt, mit sehr kleinen Basalia, welche seitlich nicht sichtbar sind, auch die Radialstücke sind klein und reichen nur zur halben Höhe, während die Interradialstücke ungewöhnlich gross sind. *Granatocrinus norwoodi* Owen und Shumard. Kohlenkalk. Hierher gehören auch die *Pentremites Elliptici* Roemer's."

Granatocrinus norwoodi is taken as the type, but, in this species, the deltoid-interradial is very small, and the main peculiarity, *i. e.*, the perforation of the deltoid, is not mentioned.

Nicholson and Lydekker, Manual of Palaeontology, Vol. I., p. 464, define the genus thus:—

"GRANATOBLASTIDAE. Calyx globular or ovoidal with a flattened or concave base and linear ambulacra. Spiracles five, piercing the deltoids; or ten grooving their lateral edges. This family includes the genera *Granatocrinus* and *Heteroblastus*."

This arrangement shows a marked inconsistency because *Heteroblastus* possesses more essentially the characters of *Cryptoblastus*, and has more affinities with it than with *Granatocrinus*, so that it would more properly belong to this genus.

Eastman's* definition is the following:—

"Calyx globular or ovoidal with flattened or concave base and long linear ambulacra. Spiracles five piercing the deltoids, or ten grooving their lateral edges. Consisting of *Granatocrinus* and *Heteroblastus*."

Here we have the same inconsistency. The last genus has all the essential characters of *Cryptoblastus*, with the exception of spine-like processes on the deltoids, though these spine-like projections are met with in many species, for example *Pentremites sulcatus*, where it seems the deltoid pieces are very much inclined to develop spiny projections. I have a number of specimens showing them of various forms and sizes. Those from the neighborhood of Ste. Genevieve show it most, whereas those from Chester or Evansville rarely show any such hypertrophic growth, while we meet with it again in specimens from Baldwin and other localities.

Another case which shows very clearly the arbitrary way

* Text-Book of Palaeontology, Vol. I., p. 196.

of classification is to be found in the diagnosis of Nucleoblastidae, Etheridge and Carpenter. This family is divided into Sub-family A. Elaeacrinidae and Sub-family B. Schizoblastidae. The only peculiarities common to both are the elliptical or ovoidal form of the body and the extremely short fork-pieces, which latter fact is not mentioned in their diagnosis. *Elaeacrinus* has its posterior deltoid divided and an elongated piece inserted, which is never the case in *Schizoblastus*. Moreover the center of the summit is firmly closed by pieces of a uniform shape and position in *Elaeacrinus*, which is not the case in *Schizoblastus* where the center is open, or closed only by the ambulacral integument.

Nicholson and Lydekker's description of this family, which is accompanied by two figures, is still more confused, reading as follows:—

"Family III. NUCLEOBLASTIDAE. Calyx usually globular or ovoidal with flattened or concave base and linear ambulacra. Spiracles distinctly double, and chiefly formed by the opposition of notches in the lancet plates and deltoids. This family includes *Elaeacrinus* (with an anal plate) and *Schizoblastus*, Fig. 332 c and d, *Cryptoblastus* and *Acentotremites* (without an anal plate)."

PROPOSED CLASSIFICATION.

The classification here offered is based mainly on the construction of the summit openings, because they exhibit a uniformity in structure, remaining always the same in their respective genera — a fact which must be of great value for classification. Next the development of the deltoids is considered, also the aspect of the outer surface (whether smooth or spiny). Whereas the general size and shape of the body, whether globose, pyriform, ovoidal, conical or clavate, depends upon the variations in the form of the parts which construct the body, and whereas the relations of these parts to each other remain the same throughout the whole class, the difference can be only specific and not generic. Nor can we attribute any more than specific value to the hydrospiric tubes, or plications, on account of the variability often observed in one and the same specimen — a fact sufficiently recognized by the very authors who regard them as being of importance for classification. All names ending in "crinus" are omitted.

I also wish to remark that this classification embraces only our American species, although most of the European species, I believe (judging from my small collection of European specimens), will fit into one or another of these genera, with the exception of aberrant forms, like some of our American ones, of which it is still doubtful whether they should be regarded as Blastoids or Cystoids, for the reception of which a separate class should be established. This class may include all doubtful specimens and those insufficiently described and doubtfully illustrated because of the fragmentary condition of the material.

CLASS BLASTOIDEAE.

A. Order Regulares.

1. Family Pentremidae.

   1. Genus Pentremites, Say.
   2. Genus Cribroblastus.
   3. Genus Saccoblastus.
   4. Genus Clavaeblastus.
   5. Genus Mesoblastus, Etheridge fil. and Carpenter.
   6. Genus Cidaroblastus.
   7. Genus Globoblastus.
   8. Genus Codonites, Meek and Worthen.

2. Family Codasteridae.

   1. Genus Codaster, Maccoy.

B. Order Irregulares.

1. Family Olivanidae.
    1. Genus Olivanites.

2. Family Eleutheroblastidae.
    1. Genus Eleutheroblastus.

Blastoideae are dicyclical Pelmatozoa. The body is composed of twenty pieces (at least in the embryonic state), arranged in two circles of even numbers and an irregular number of accessory pieces (say poral pieces), with the exception of one order, Irregulares, where one or the other circle contains an odd piece, a total difference from all others. All were supported by a slender round or triangular column, except one genus (*Eleutheroblastus*) as far as known. Geologically they belong to the Palaeozoic Age, commencing in the upper Silurian, gradually increasing until they reach their culmination point in the upper Subcarboniferous, and becoming extinct with the close of the Chester limestone. Geographically they have been observed in Europe, Australia and America, from which country the greatest number of species has been described.

Family Pentremidae.

Body of various forms, all supported by a round or triangular column. None of the summit openings permanently closed except by the ambulacral integument. All of this family, when perfectly preserved, are known to possess pinnulae and probably many of them, if not all, had a short proboscis.

1. Genus Pentremites.

General form of body globose, ovoid, conical, pyriform or club shaped. Central orifice never closed except by the ambulacral integument, surrounded by eleven openings, which appear externally as five, and are constructed by the junction of deltoid and lancet pieces. Deltoid pieces variable, visible externally in the adult species, and in others they are never visible externally. Ambulacrum rather broad. Column round.

This genus will include the following species: —

1. Pentremites abbreviatus, Hambach, 1880. Chester limestone.

This species is erroneously taken to be identical with *Pentremites godoni*, by Etheridge, Jr., and P. H. Carpenter, C. R. Keyes, and others. In so doing they mistake the facts, and I must say that none of these gentlemen is acquainted with this species. If they were, or if they had taken the trouble to compare my figure and description* with *Pentremites godoni*, they would have seen that they are not one and the same species. Carpenter's figure† does not represent the essential characters given in my description, which makes it differ from the typical *Pentremites godoni*. My species is quite rare, and has, as far as I know, been found only at one small locality, about 500 feet square, in a semi-oolitic limestone, although the whole country around is rich in *Pentremites*, especially in *Pentremites sulcatus*. The specimen figured by me is the largest I have ever seen of this species. In all specimens, whether large or small, the transverse diameter is $\frac{1}{4}$ larger than the vertical one. The interambulacral space is more rounded, also the ambulacrum, and there is not a sharp crest at both sides of it as we find in *Pentremites godoni*.

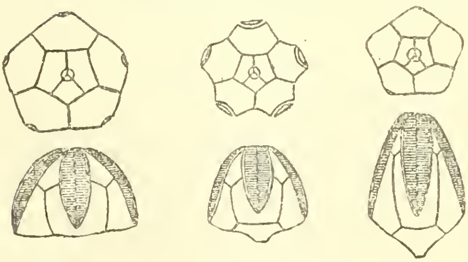


Fig. 12.

a. b. c.

a. Pentremites abbreviatus.
b. " godoni.
c. " florealis.

* Transactions St. Louis Academy of Science, Vol IV., p. 155, Fig. 3.

† Catalogue of the Blastoidea, Plate II., Fig. 4.

In a lateral view the base is never visible. For comparison see the accompanying figure 12.

2. Pentremites angularis, Lyon, 1860. Chester limestone.

3. Pentremites basilaris, Hambach, 1880. Chester limestone.

4. Pentremites Broadheadi, Hambach, 1880. Chester limestone.

5. Pentremites burlingtonensis, Meek & Worthen, 1869. Burlington limestone.

6. Pentremites calycinus, Lyon, 1860. Chester limestone.

7. Pentremites cervinus, Hall, 1858. Chester limestone.

8. Pentremites chesterensis, Hambach, 1880. Chester limestone.

9. Pentremites clavatus, Hambach, 1880. Chester limestone.

10. Pentremites conoideus, Hall, 1856. Warsaw limestone.

    This species is synonymous with *Pentremites koninckana*, Hall, which is only the young stage of *P. conoideus*.

11. Pentremites elegans, Lyon, 1860. Chester limestone.

    This species is synonymous with the one designated by Dr. Troost as *tennesseae*, nom. nud. The description of Troost was never published. The specimens so designated by Troost, now in the collection of the Smithsonian Institution, No. 33,072, are the same as those described by Lyon as *Pentremites elegans*.

12. Pentremites elongatus, Shumard, 1855. Burlington limestone.

13. Pentremites florealis, v. Schlotheim, 1820. Chester limestone.

    Pentremites symmetricus, Hall. Chester limestone.
    Pentremites altus, Rowley.

Shumard and many later authors confound this species with *Pentremites godoni*, which is a sad mistake because there is a considerable difference between these two species. In the typical *P. florealis* the body is more elongated, the base portion drawn out and more prolonged than in *Pentremites godoni*, and the plications of the ambulacral integument are coarser than in *P. godoni*. The typical *Pentremites florealis* is comparatively rare in Alabama and Kentucky but not so at Chester, Illinois, where *Pentremites godoni* does not occur at all. We find it again at Waterloo, Illinois, associated with *Pentremites florealis*, but it is by far the predominating species here.

14. Pentremites gemmiformis, Hambach, 1884. Chester limestone.

15. Pentremites godoni, De France, 1818. Chester limestone.
Kentucky arterial fossil, Parkinson, 1808.
Pentremites globosus, Troost.

16. Pentremites hemisphericus, Hambach 1880. Chester limestone.

17. Pentremites nodosus, Hambach 1880. Chester lime stone.

18. Pentremites obesus, Lyon, 1857. Chester limestone.

19. Pentremites pyriformis, Say, 1825. Chester limestone.
Pentremites subconoideus, Meek, a young form of *pyriformis*.

This species differs from *P. florealis*, its nearest relative, in having its greatest diameter at the apex of the ambulacrum, dividing the calyx in two equal halves, *i. e.*, the distance from the articulation surface of the column equals the distance from the apex of the ambulacrum to the summit.

20. Pentremites spinosus, Hambach, 1880. Chester limestone.

21. PENTREMITES SULCATUS, Roemer, 1852. Chester limestone.
Pentremites cherokeeus, Troost M. S.
Pentremites robustus, Lyon.
Pentremites laterniformis, Owen and Shumard.

The latter, which has been regarded as a synonym for *Pentremites obliquatus*, is the cast of *Pentremites sulcatus*. The confounding of this species with *P. obliquatus* must have been caused by assuming that a cast of *obliquatus* would furnish an elongated prismatic lower calyx part, as we have in *P. laterniformis*, which is due to the internally straight base portion of the fork pieces in *Pentremites sulcatus*, as I have described and figured years ago. Moreover all *Pentremites laterniformis* have been described as coming from the Chester limestone, where such casts are frequently met with, but the *Saccoblastus obliquatus* (= *P. laterniformis*, *Troostocrinus laterniformis*, *Tricoelocrinus obliquatus*) does not occur in this formation and so far has been found only in the Warsaw or Keokuk formation.

22. PENTREMITES BRADLEYI, Meek. Subcarboniferous.

2. Genus CRIBROBLASTUS.

General form of body elliptical or globose, of medium size, seldom over ½ inch vertical diameter. Ambulacrum narrow, linear, and extending almost over the whole body. Central opening never closed, except by ambulacral integument, surrounded by eleven openings constructed by the junction of deltoid and lancet piece, very small and never confluent with each other. Anal opening on the posterior side between two genital openings, from which it is separated by two fine septa. Deltoid pieces very variable, occupying from $\frac{1}{10}$ to $\frac{3}{4}$ of the interambulacral space. Base portion small, more or less depressed. Column round. This genus will include the following species.

1. CRIBROBLASTUS CORNUTUS, F. B. Meek and A. H. Worthen. St. Louis limestone.
   Pentremites cornutus, Meek and Worthen.
   Granatocrinus cornutus, Shumard.
   Elaeacrinus cornutus, Shumard.
   Heteroblastus cornutus, Etheridge and Carpenter.

2. CRIBROBLASTUS CURTUS, Shumard. St. Louis limestone.
   Pentremites curtus, Shumard.
   Granatocrinus curtus, Shumard.
   Orbitremites curtus, Bather.

*3. CRIBROBLASTUS GRANULOSUS, Meek and Worthen. Burlington limestone.
   Pentremites granulosus, Meek and Worthen.
   Granatocrinus granulosus, Meek and Worthen.
   Schizoblastus granulosus, Etheridge and Carpenter.

4. CRIBROBLASTUS KIRKWOODENSIS, B. F. Shumard. St. Louis limestone.
   Elaeacrinus kirkwoodensis, Shumard.
   Cryptoblastus kirkwoodensis, Keyes.
   Nucleocrinus kirkwoodensis, Miller.
   Schizoblastus missouriensis, Etheridge and Carpenter.

5. CRIBROBLASTUS LOTOBLASTUS, C. A. White. Lower Carboniferous gr.
   Granatocrinus lotoblastus, White.
   Orbitremites lotoblastus, Bather.
   Schizoblastus lotoblastus, Weller.

   It is very doubtful whether this species belongs here. Nothing, however, can be said until more material has been collected. The only specimen known is the type of White's description, now in the collection of the Smithsonian Institution, No. 8541. The specimen is much incrusted and does not show anything of the summit openings which are mostly covered by foreign matter.

6. CRIBROBLASTUS MELO, Owen and Shumard. Burlington limestone.
   Pentremites melo, Owen and Shumard.
   Granatocrinus melo, Shumard.
   Elaeacrinus melo, Shumard.
   Cryptoblastus melo, Etheridge and Carpenter.

7. Cribroblastus melonoides, Meek and Worthen. Burlington limestone.
Granatocrinus melonoides, Meek and Worthen.
Schizoblastus melonoides, Etheridge and Carpenter.

*8. Cribroblastus neglectus, Meek and Worthen. Burlington limestone.
Granatocrinus neglectus, Meek and Worthen.
Schizoblastus neglectus, Etheridge and Carpenter

*9. Cribroblastus pisum, Meek and Worthen. Burlington limestone.
Granatocrinus pisum, Meek and Worthen.
Cryptoblastus pisum, Etheridge and Carpenter.
Schizoblastus pisum, Etheridge and Carpenter.

*10. Cribroblastus potteri, Hambach. Burlington limestone.
Pentremites potteri, Hambach.
Schizoblastus sayi, Etheridge and Carpenter.

11. Cribroblastus projectus, Meek and Worthen. Burlington limestone.
Pentremites melo, var. *projectus*, Meek and Worthen.
Granatocrinus projectus, Meek and Worthen.
Cryptoblastus projectus, Bather.

*12. Cribroblastus roemeri, Shumard. Chemung and Chouteau limestone.
Pentremites roemeri, B. F. Shumard.
Granatocrinus roemeri, Shumard.
Orbitremites roemeri, Bather.
Schizoblastus roemeri, Keyes.

*13. Cribroblastus sampsoni, Hambach. Chouteau lime stone.
Pentremites sampsoni, Hambach.
Schizoblastus sampsoni, Etheridge and Carpenter.
Schizoblastus roemeri, Keyes.

This species is not synonymous with *C. roemeri* as Keyes takes it. The external ornamentation of the interambulacrum differs very much from that of *roemeri* (see Pl. V., Figs. 9 and 10). Moreover the relative width of the interambulacrum is about $\frac{1}{5}$

greater than in *C. roemeri*. *Cribroblastus roemeri* is much rarer than *C. sampsoni*.

*14. Cribroblastus sayi, Shumard. Burlington limestone.
Pentremites sayi, Shumard.
Granatocrinus sayi, Shumard.
Schizoblastus sayi, Etheridge and Carpenter.
Schizoblastus potteri, Etheridge and Carpenter.

My species *C. potteri* has been taken as synonym for *C. sayi*. The interambulacrum of *C. sayi* is broader and transversely striated and more elevated than in *C. potteri*. The base portion in *C. sayi* is depressed so that the basal part is not visible in a lateral view, which is the case in *C. potteri*. The slit-like openings at the summit in both species, as well as in *C. melonoides*, are due to the ambulacral integument in the immediate neighborhood of the genital openings. The perfectly round form of the genital openings can be sufficiently proved in weathered specimens, where the ambulacral integument is eroded. Moreover it seems that this species is very rare at Burlington, as of all specimens coming from that locality, I have not noticed more than a dozen typical specimens. Shumard's type specimen came from Marion County in the neighborhood of Palmyra. It also occurs in Boone County, St. Louis County, and at Louisiana, Missouri.

15. Cribroblastus shumardi, Meek and Worthen. Burlington limestone.
Granatocrinus shumardi, Meek and Worthen.
Mesoblastus shumardi, Etheridge and Carpenter.
Schizoblastus shumardi, Etheridge and Carpenter.

For difference of those species marked with an asterisk, see Plate V., Fig. 9, 10, 11, 12, 13, 14, 15.

3. Genus Saccoblastus.

General form of the body pyriform, compressed cylindrically, or club-shaped. Ambulacra narrow and linear, generally, sunk into the fork piece sinus so that the surface does not touch the upper margin of the fork piece sinus. Lower part of the body shows three distinctly depressed areas; the amount of depression varies in the different species. Interambulacral surface smooth or very finely striated. Summit opening never closed except by the ambulacral integument. Genital openings ten, of a slit-like appearance, on account of the orifice opening obliquely. Anal opening so far below the genitals that in large specimens it is almost ¼ inch below the summit, and as far as known not covered. All specimens which I have had an opportunity to examine (over six hundred) did not show any sign of a covering. Column triangular. This genus comprises *Troostocrinus*, *Tricoelocrinus* and *Metablastus*, and to show the gradual transformation from one to the other I have given good figures of all our American species on Plate IV. All described specimens are from the Warsaw limestone or below from the lower Subcarboniferous rocks.

1. Saccoblastus bipyramidalis, Hall. Warsaw limestone.
   Pentremites bipyramidalis Hall.
   Troostocrinus bipyramidalis Hall.
   Metablastus bipyramidalis, R. Etheridge fil. and P. H. Carpenter.

2. Saccoblastus lineatus, B. F. Shumard. Burlington limestone.
   Pentremites lineatus, Shumard.
   Troostocrinus lineatus, Shumard.
   Metablastus lineatus, Etheridge fil. and Carpenter.

3. Saccoblastus obliquatus, Roemer. Warsaw limestone.
   Pentatrematites obliquatus, Roemer.
   Pentremites occidentalis, Shumard.
   Tricoelocrinus obliquatus, R. Etheridge fil. and Carpenter.
   Troostocrinus laterniformis, Shumard.

4. Saccoblastus woodmani, Meek and Worthen. Warsaw and Keokuk limestone.
   Tricoelocrinus woodmani, Meek and Worthen.
   Troostocrinus woodmani, Meek and Worthen.

5. Saccoblastus wortheni, I. Hall. Warsaw limestone and Keokuk.
   Metablastus wortheni, R. Etheridge fil. and Carpenter.

Pentremites grosvenori, Shumard.
Troostocrinus grosvenori, Etheridge and Carpenter.
Troostocrinus nitidulus, S. A. Miller and Gurley.
Metablastus varsouviensis, Etheridge and Carpenter.
Pentremites varsouviensis, Meek and Worthen.
Metablastus wachsmuthi, Gurley.
Troostocrinus wachsmuthi, Gurley.

6. Saccoblastus meekianus, R. Etheridge fil. and Carpenter. Warsaw limestone.
Tricoelocrinus meekianus, Eth. and Carp.

4. Genus Clavaeblastus.

General form of the body club-shaped, or elliptical. Ambulacra narrow and linear. Deltoids not visible externally, except on the posterior side, where the deltoid piece supports the anal opening which lies outside of the genital openings, which are confluent and surround the central opening. Column round. Upper Silurian and Devonian. If more material should be collected from the Devonian rocks, it may bring to light characteristics as yet unknown, which may necessitate the creation of a new genus for this form.

This genus will include the following species: —

1. Clavaeblastus americana, W. H. Barris. Hamilton group.
Pentremitidea americana, W. H. Barris.

2. Clavaeblastus filosa, I. F. Whiteaves. Hamilton group.
Pentremitidea filosa, I. F. Whiteaves.
Pentremites whitei, Hall.

3. Clavaeblastus milwaukensis, S. Weller. Hamilton group.
Pentremitidea milwaukensis, S. Weller.

4. Clavaeblastus reinwardtii, G. Troost. Niagara group.
Pentremites reinwardtii, Troost.
Troostocrinus reinwardtii, Shumard.
Pentremites subcylindricus, Hall and Whitfield.

5. Genus Mesoblastus, Etheridge fil. and Carpenter.

Body small, round or elliptical. Base small and flat. Ambulacra narrow and convex, extending the whole length of the body. Ambulacral integument scroll-like. Deltoids very small, hardly visible in a lateral view, but more so in a summit view, except the posterior one which supports the anal opening, which is outside of the genital openings. Genital openings not confluent, but connected by a small sulcus, running from one to the other in a V shape. Column round. With only one species.

1. Mesoblastus glaber, Meek and Worthen. St. Louis limestone.
   Granatocrinus glaber, Meek and Worthen.

6. Genus Cidaroblastus.

General form of body elliptical or globose. Ambulacra narrow and linear, extending almost over the whole surface of the body. Central opening never closed except by ambulacral integument. Genital openings ten, constructed by the junction of the deltoid and lancet pieces, very small and never confluent with each other. Anal opening on the posterior side between two of the genital openings. Deltoid pieces very large in all known species, occupying almost half of the interambulacrum. Whole interambulacral space covered with large tubercles for the attachment of spines. Base pieces small and depressed, being never visible in a side view. Column round. This genus contains the typical *Granatocrinus* of Dr. Troost of which I give three figures on Plate III., drawn from the type specimens in the Troost Collection now in the Smithsonian Institution. Geological position, in the Subcarboniferous rocks.

1. Cidaroblastus granulatus, Roemer. Subcarboniferous.
   Pentatrematites granulatus, Roemer.
   Granatocrinus cidariformis, Troost.
   Granatocrinus globosus, Troost.
   Orbitremites granulatus, Bather.

7. Genus Globoblastus.

General form of body globose or elliptical. Ambulacrum narrow and linear, extending almost over the whole surface of the body. Central opening never closed except by ambulacral integument. Genital openings five, piercing the deltoid pieces and bifurcating in the substance of the shell toward the interior. Anal opening large to receive the anal tube which is on the posterior side in the center of this bifurcation, making this opening twice as large as the others. Deltoid pieces of variable size, in some species occupying almost half of the interambulacral surface. Base small and very much depressed. Column round.

My reason for not using the name *Granatocrinus* is sufficiently explained in the foregoing pages. Besides its ending in "crinus" the genus contains so many different forms among the various authors, that it is apt to be misleading to the student. The name *Orbitremites*, Austin, which Mr. Bather adopted as the one which should have priority, is only a name without a generic diagnosis, and therefore equally inadequate. To avoid all confusion I propose the above used name. The genus includes the following species: —

1. Globoblastus norwoodi, Owen and Shumard. Burlington limestone.

   Pentremites norwoodi, Owen and Shumard.
   Granatocrinus norwoodi, Shumard.
   Orbitremites norwoodi, F. A. Bather.

8. Genus Codonites.

General form of the body, bell or star-shaped. Ambulacra narrow and linear, extending out and downward, thus giving a more or less star-shaped appearance to the summit. Central opening very small and usually covered by the ambulacral integument. Genital openings, long slits at each side of the ambulacrum. Anal opening large and lateral. Base, funnel-shaped. Column round and large for the size of the specimen when compared with *Pentremites*.* All known species belong to the lower Subcarboniferous. This genus will include the following species: —

1. Codonites conicus, C. Wachsmuth and F. Springer. Kinderhook gr.
   Orophocrinus conicus, Wachsmuth and Springer.
2. Codonites campanulatus, Hambach. Lower Burlington limestone.
   Orophocrinus campanulatus, Keyes.
   Orophocrinus stelliformis, Etheridge and Carpenter.
3. Codonites fusiformis, Wachsmuth and Springer. Kinderhook gr.
   Orophocrinus fusiformis, Wachsmuth and Springer.
4. Codonites gracilis, Meek and Worthen. Lower Burlington limestone.
   Orophocrinus gracilis, Meek and Worthen.
5. Codonites stelliformis, Owen and Shumard. Lower Burlington limestone.
   Pentremites stelliformis, Owen and Shumard.
   Orophocrinus stelliformis, Meek and Worthen.
6. Codonites whitei, Hall. Burlington limestone.
   Codastus whitei, Hall.
   Orophocrinus whitei, Whitfield.

2. Family Codasteridae.

1. Genus Codaster.

General form of the body bell-shaped or obconical. Ambulacral side more or less horizontal. Ambulacra linear. Mouth small and central. Anus large and lateral, placed between two ambulacra. Numerous slits at each side of the ambulacrum, except on the posterior side, *i. e.*, on the side which faces the anal opening, where they are wanting. Inter-

* It is more closely ralated to *Pentremites* than to *Codaster* on account of the hydrospires.

ambulacral areas often acute and projecting beyond the summit. Column thin and round. Geological range from the upper Silurian to the Coal Measures. The following species belong to this genus: —

1. CODASTER ATTENUATUS, Lyon. Devonian.
   Codaster attenuatus, Owen.
   Heteroschisma alternatum, Wachsmuth.
   Heteroschisma alternatum var. *elongatum*, Wachsmuth.

2. CODASTER AMERICANUS, Shumard. Devonian.

3. CODASTER CANADENSIS, E. Billings. Devonian.
   Codaster hindei, Whiteaves.

4. CODASTER GRACILIS, Wachsmuth. Devonian.
   Heteroschisma gracilis, Wachsmuth.

5. CODASTER KENTUCKYENSIS, Shumard. Lower Subcarboniferous.
   Pentremites kentuckyensis, Shumard.
   Phaenoschisma, Etheridge and Carpenter.

6. CODASTER PULCHELLUS, S. A. Miller and C. B. Dyer. Niagara gr.
   Stephanocrinus puchellus, Miller and Dyer.

7. CODASTER PYRAMIDATUS, Shumard. Devonian.
   Codaster alternatus (pars), Lyon.

8. CODASTER SUBTRUNCATUS, Hall. Devonian.
   Pentremites subtruncatus, Hall.
   Heteroschisma gracile, Wachsmuth.
   Troostocrinus subtruncatus, Etheridge and Carpenter.

B. ORDER IRREGULARES.

1. FAMILY OLIVANIDAE.

1. Genus OLIVANITES.

General form of the body oval or round. Base very small and depressed. Fork pieces very short, hardly more than $\frac{1}{6}$ of the whole length of the body. Ambulacra narrow, linear and extending the full length of the body. Deltoids very large, occupying nearly $\frac{5}{6}$ of the whole length. Genital openings constructed by the junction of the deltoid and lancet piece, and not confluent. Poral pieces varying in number according to the size of the species. Center of the summit closed by additional pieces. The main opening (the anal ?) is lateral and posterior, *i. e.*, the posterior deltoid is divided in half and an elongated piece inserted as a support for the opening. Column round.

Nearly all the material collected so far is of such a nature as to make a more accurate description impossibie. Geologically they belong to the Devonian. Here we find the first irregularity in the construction of the calyx. It is difficult to say whether the elongated piece should be counted to the ambulacral or the interambulacral cycle, giving one or the other an old number of pieces.

The name *Nucleocrinus*, introduced by Conrad in 1842, is here rejected, first because of its ending in "crinus," and secondly because of the insufficient diagnosis, which reads as follows: "This genus differs from *Pentremites sayi* in having only one perforation at top, which is central."* On account of this insufficiency it was not adopted by most of our American palaeontologists. It is absolutely impossible to recognize or identify a specimen from the above description, accompanied by an incorrect drawing.

Roemer's name *Elaeacrinus* has to be rejected also on account of its ending in "crinus." By so doing, and not to increase the nomenclature with synonyms, I have adopted Lyon's designation as the most suitable one. This genus will include the following species: —

1. Olivanites angularis, Lyon. Devonian.
   Nucleocrinus angularis Etheridge and Carpenter.
   Elaeacrinus angularis, Shumard.

*2. Olivanites conradi, Hall. Devonian.
   Nucleocrinus conradi, Hall.
   Elaeacrinus conradi, Hall.
   Nucleocrinus verneuili, Hall.

---

* Journal of the Academy of Natural Sciences of Philadelphia, 1842, Vol. VIII., page 280, Pl. XV., Fig. 17.

3. OLIVANITES ELEGANS, T. A. Conrad. Devonian.
   Nucleocrinus canadensis, H. Montgomery.
   Nucleocrinus hallii, L. Vanuxem.
   Elaeacrinus elegans, Shumard.
   Nucleocrinus venustus, Miller and Gurley.

*4. OLIVANITES GREENI, S. A., Miller and W. F. E. Gurley. Devonian.
   Nucleocrinus greeni, Miller and Gurley.

*5. OLIVANITES GLOBOSUS, Troost. Devonian.

6. OLIVANITES LUCINA, Hall. Devonian.
   Nucleocrinus lucina, Hall.

*7. OLIVANITES MELONIFORMIS, W. H. Barris. Devonian.
   Elaeacrinus meloniformis, Barris.

8. OLIVANITES OBOVATUS, W. H. Barris. Devonian.
   Elaeacrinus obovatus, Barris.

9. OLIVANITES VERNEUILI, Lyon. Devonian.
   Pentremites verneuili, Troost.
   Elaeacrinus verneuili, Roemer.
   Nucleocrinus verneuili, Bather.

Those marked with an asterisk may have to be placed in another genus or may prove to be identical with one or another already known species, which facts can only be established when more material for comparison is available.

2. FAMILY ELEUTHEROBLASTIDAE.

1. Genus ELEUTHEROBLASTUS.

General form elliptical, truncated at the summit and subtriangular at the base. Base very irregular, subtriangular at the lower part, and prolonged on one of its sides to a remarkable length. It consists of three pieces, one small rhombic piece and two large pieces prolonged nearly to the middle of the calyx. Fork pieces four, non-symmetrical, each having a long sinus in the center for the reception of the ambulacrum. The two middle pieces have a shorter sinus, whereas the two lateral pieces have a sinus at least ⅛ inch longer, and, consequently, a longer ambulacrum. The fifth fork piece is shortest, being only half as long as the others, but much wider and rests upon the upper edges of the two large basals. This piece has a very broad but short sinus, and corresponding ambulacrum. Deltoids five and small. Ambulacra narrow and linear; the fifth broad and triangular and lying horizontally on the summit. Mouth central. No anal opening visible. Genital openings five, each one divided by a septum. I consider the side with the short and broad ambulacrum the posterior part of the calyx. No column. Devonian.

1. Eleutheroblastus canedayi, B. F. Shumard and L. P. Yandell. Devonian.
   Eleutherocrinus canedayi, Shumard and Yandell.

2. Eleutheroblastus whitfieldi, Hall. Hamilton group.
   Eleutherocrinus whitfieldi, Hall.

The following species are insufficiently described and illustrated to be identified and classified with certainty: —

Blastoidocrinus carchariaedens, Billings.
Pentremites decussatus, Shumard.
Pentremites maia, Hall.
Pentremites leda, Hall.
Pentremites calyce, Hall.
Pentremites lycories, Hall.
Pentremites whitei, Hall.
Codaster blairi, Miller and Gurley.
Codaster jessieae, Miller and Gurley.
Nucleocrinus venustus, Miller and Gurley.
Granatocrinus sphaeroidalis, Miller and Gurley.
Granatocrincus winslowi, Miller and Gurley.
Granatocrinus aplatus, Rowley and Hare.
Granatocrinus concinnulus, Rowley and Hare.
Granatocrinus pyriformis, Rowley and Hare.
Granatocrinus exiguus, Rowley and Hare.

Codonites inopinatus, Rowley and Hare.
Granatocrinus excavatus, Rowley and Hare.
Codaster gracillimus, Rowley and Hare.
Codaster grandis, Rowley.
Lophoblastus conoideus, Rowley.
Lophoblastus marginulus, Rowley.
Carpenteroblastus pentagonus, Rowley.
Carpenteroblastus magnibasis, Rowley.
Carpenteroblastus pentalobus, Rowley.
Carpenteroblastus stella, Rowley.
Codaster laeviculus, Rowley.
Granatocrinus calycinus, Rowley.
Granatocrinus spinuliferus, Rowley.
Pentremites benedicti, Rowley.
Troostocrinus dubius, Rowley.

DESCRIPTIONS OF NEW SPECIES.

PENTREMITES TULIPAFORMIS n. s.

Plate IV., Fig. 10, 11.

Body oval in outline with the broadest part downward and the greatest transverse diameter at the apex of the ambulacrum. Basals small, each rounded and nodose, causing the articulation surface of the column to become a little depressed or sunk between these three nodules and therefore not visible in a lateral view. Ambulacrum broad, leaf-like and groove-like, occupying three-fourths of the whole length of the body. Poral pieces ten to one-eighth of an inch. Interambulacral space smooth and not depressed, giving the lower part of the body a somewhat rounded form. Lateral expansion of the deltoid occupying about one-third of the whole length of the calyx. Genital openings and mouth small and close together. This species belongs to the Chester limestone and is found at Kaskaskia, Illinois, but is by no means common.

Pentremites obtusus n. s.

Fig. 13.

Among the great number of *Pentremites* (*Pentremites conoideus*) so characteristic of the Boonville locality, we find by close examination of a large amount of material that they are not all one and the same kind and we can readily pick out a number which, although resembling very much *Pentremites conoideus*, differ constantly in certain characters from this species, so that we are forced to regard them as a distinct species. Their body is conical with a flat basal portion, the small basal pieces not visible in a side view; ambulacrum narrow with a rounded surface and extending to the base of the body. Vertical diameter never, even in a small specimen, greater than the horizontal one, by which it can easily be recognized from *P. conoideus*. Interambulacral space smooth and not as much depressed as we find it in *Pentremites conoideus*. Genital openings small and close together. It is a distinct Warsaw species.

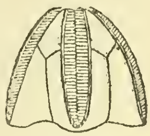


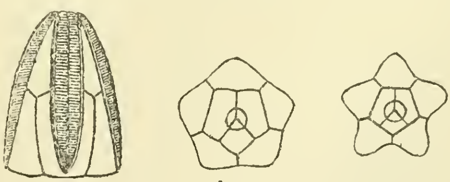
Fig. 13.

Geological position and locality: It occurs in the Warsaw limestone of Boonville, Missouri.

Pentremites angustus n. s.

Fig. 14.

Body elongate, obtuse, conical. Base small, flat and not visible in a side view. Ambulacrea as long as the whole body and nearly three-sixteenths of an inch in width, extending a little above the fork piece sinus and slightly rounded on the surface. Poral openings twelve to one-eighth of an inch. Interambulacral space smooth and not depressed in the center. Lateral expansion of the deltoid externally visible and occupying fully one-half of the



a. b. c.

Fig. 14.

a. Pentremites angustus.
b. " " base view.
c. Pentremites conoideus, base view.

whole length of the body. Genital openings small and close together, appearing on the outer surface as five, of which one is twice as large as the others. This species resembles somewhat *Pentremites conoideus* though it is easily recognized and distinguished from *P. conoideus* by not having the summit as acute as *conoideus*, by its wider ambulacra and by its interambulacral space not being depressed as in *conoideus*. It is distinguished from *Pentremites elongatus* by its more conical form, perfectly flat basal portion, having the greatest diameter of the body right at the apex of the ambulacrum and not having the interambulacral space finely striated as we find it in *Pentremites elongatus*. It belongs to the Chester limestone, but has been so far known only from Washington County in Arkansas.

PENTREMITES TURBINATUS n. s.

Plate V., Fig. 6.

Body turbinate or inverted pyramidal. Base large for the size of the specimen and funnel shaped. Fork pieces elongate, square and large; sinus broad extending down only half the length of the piece. Ambulacrum broad, leaf-like and flat. Poral pieces eleven to one-eighth of an inch. Deltoids externally not visible. Interambulacral space rather flat and smooth. Genital openings close together. Greatest transverse diameter at the apex of the ambulacrnm which occupies the upper third of the body.

Geological position and locality: Chester limestone, Evansville, Illinois. Very rare.

PENTREMITES RUSTICUS n. s.

FIG. 15.

Body almost cylindrical, *i. e.*, the diameter at the base is as great as near the summit. Basal plates very small and not visible in a lateral view. Ambulacra as long as the body with a somewhat rounded surface and sunk into the fork piece sinus which has a sharp and prominent margin. Poral openings thirteen to one-eighth of an inch. Lateral expression of deltoid one-third of the whole length of the body,

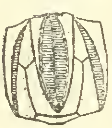


FIG. 15.

extending near the summit prominently outward, giving to the body a square appearance. Interambulacral space not depressed as in *Pentremites conoideus* and covered with fine striae, running parallel to the sutures. Genital openings small and close together as in the foregoing species.

Geological position and locality: It occurs in the Chester limestone and is known so far only from Washington County, Arkansas.

Pentremites kirki n. s.

Plate V., Fig. 18.

General form of the body cylindrical, about $\frac{3}{4}$ of an inch in length and $\frac{5}{16}$ of an inch in width. Base very robust and funnel shaped, with a large articulation surface for the column, almost as wide as in *Codonites*. Distance from the articulation surface of the column to the apex of the ambulacrum about two-fifths of the entire length of the body. Ambulacra broad and slightly rounded with a very coarse plicable integument with only eight plications to one-eighth of an inch. Interambulacral space rather narrow, with a slight depression in the center and a sharp, projecting, spiny crest at the apex of the ambulacrum. Whole surface of the interambulacral space and the base portion ornamented with fine striations, running parallel to the sutures.

Deltoids hardly visible externally, but the summit projects about $\frac{1}{16}$ of an inch above the sharp point of the fork piece. Genital openings, as in *Pentremites elongatus* or *burlingtonensis* where the anterior portion, or the outer septa of the deltoid base, divide each opening in two, while the posterior one is divided into three so that the summit shows very distinctly twelve openings.

Geological formation and locality: Lower Burlington limestone.

It gives me great pleasure to name this beautiful little Blastoid in honor of Mr. E. Kirk, the lucky finder, who is a very energetic and prominent young collector.

Pentremites bradleyi Meek.

Plate V., Fig. 7.

Body small, obtuse, conical. Basal portion almost flat, and resembling that of *Pentremites conoideus* very much, but being more rounded and having a larger articulation surface for the column, in proportion to its size, than *Pentremites conoideus*. Ambulacra broad, excavated along the middle, and having rather narrow integumental plications, there being about twelve to one-eighth of an inch. Deltoids visible externally. Genital openings as in all true *Pentremites*.

This species was first described by Meek, but merely in a foot note, comparing it with *Pentremites koninckiana* = *conoideus* Hall. It differs from *Pentremites conoideus* in being more obtuse, with broader and more deeply excavated ambulacra than *Pentremites conoideus*, in which the ambulacra are narrow, more rounded, and the surface plications coarser. The interambulacral spaces are depressed more in *Pentremites conoideus* than in this species. It differs from *Pentremites godoni* in being not as round, with more depressed ambulacra, and in not having the sharp crest-like margin around the sinus.

Geological formation and locality: Subcarboniferous on the Divide between Ross Fork and Lincoln Valley, Montana. First mentioned in F. V. Hayden's Sixth Annual Report of the United States Geological Survey of the Territories, 1872, p. 470. Types in the Smithsonian Collection, numbered 24,529.

Pentremites serratus n. s.

Plate IV., Fig. 9.

Body robust and resembling *Pentremites sulcatus* very much. Base flat and disk-like, showing a distinctly triangular depression around the articulation surface of the column. Ambulacra concave, broad, leaf-like, and sunk so that the surface does not reach the upper margin of the sinus. Interambulacral area not so depressed as in *Pentremites sulcatus*, with a very prominent and coarsely serrated margin at each side of ambulacrum from the base of the sinus to the deltoid suture. External deltoid surface rather convex, smooth, with a sharp prominent base point, projecting much over the summit. Whole surface finely striated. Poral pieces 9 to $\frac{1}{8}$ inch. Genital openings as in *Pentremites sulcatus*. All my specimens vary from $\frac{1}{2}$ to $1\frac{1}{2}$ inches in diameter. Transverse diameter one-fourth greater than the vertical diameter. The serrated edge of each side of the ambulacrum distinguishes this species readily from *Pentremites sulcatus*, its nearest ally.

The geological formation is the Chester limestone, but I have never found it at Chester or Evansville, Illinois, or around there. It occurs at Ste. Genevieve, Missouri, and at Baldwin, Illinois.

Cribroblastus incisus n. s.

Plate V., Fig. 2.

Body globose, of medium size, seldom more than $\frac{3}{8}$ inch in diameter. Base very small, depressed, not visible in a lateral view. Ambulacrum narrow, linear, running almost over the whole surface of the body. Deltoid pieces very small, visible externally, but entirely confined to the summit. Interambulacral area convex and granulated, with a deep suture in the center and a lunary impression at each side of the ambulacral margin, dividing each side of the ambulacral sinus in two; and a little spine-like projection at the apex of the sinus readily distinguishes it from *C. melo* and other allied forms. Genital openings very small but not confluent with each other.

Geological formation and locality: Lower Burlington limestone, Burlington, Iowa.

Cidaroblastus parvus n. s.

Plate V., Fig. 1.

Body ovoidal, a little wider at the summit than at the base. Base very small and depressed, but not as much as in the typical specimen of this genus. Ambulacrum narrow and linear, running almost over the whole surface of the body. Fork pieces broad, occupying a little more than half the vertical height of the calyx, with an elongated depression in the center of the interambulacrum where two of them join. Deltoid very broad, occupying nearly half the interambulacrum, covered with small granules, arranged in regular transverse rows, for the reception of little spines. Genital openings very small, not confluent.

Of this unique species I have several silicious casts, as well as the surrounding molds, which show distinctly the fine spines adhering to them. All the specimens are of a cherty nature and on the whole not as well preserved as most other specimens, but, nevertheless, showing all the above described characters very distinctly.

Geological formation and locality: In cherty rock of the St. Louis age, in southwestern Missouri.

Cribroblastus verrucosus n. s.

Plate V., Fig. 3.

General form of body globose, vertical and transverse diameters equal. Basals very small and almost concealed by the column, or extending very little beyond it. Ambulacra narrow and linear, running almost over the whole surface of the body. Fork pieces very short occupying hardly one-fourth of the vertical diameter of the body with a very distinctly depressed suture. Deltoids very broad, occupying fully three-fourths of the vertical length of the body, separated from the upper fork piece suture by a double linear depression. The whole interambulacral space is rounded and ornamented by coarse granulation very irregularly arranged.

This species is easily separated from its nearest relatives, as *Cribroblastus sayi* (*Pentremites sayi* of Shumard), by its coarse granular surface. Of this nice unique Blastoid I possess only a silicious cast and mould though sufficiently preserved to recognize its distinction from similar species.

Geological formation and locality: It was discovered in a cherty rock of the Burlington formation at Allenton, St. Louis County, Mo.

Cribroblastus tenuistriatus n. s.

Plate V., Fig. 16.

Body small and oval in outline, being a little wider at the summit than at the base. Basals very small but visible in a lateral view. Ambulacra narrow and linear, not extending over the whole surface of the body, occupying only three-fourths of its entire length. Deltoids about one-third of the whole length, the whole interambulacral space rounded and with a lancet-shaped longitudinally striated elevation extending from the base to the apex of the deltoid whereas the deltoid, surface and the surface at both sides of the lancet-shaped elevation are ornamented with little granules arranged in a distinctly transverse manner. Genital openings very small and formed by the junction of the deltoid and lancet piece. Vertical diameter one-third greater than the transverse. Whole length of the specimen $\frac{5}{16}$ of an inch, width $\frac{4}{16}$ inch.

Geological position and locality: In the Burlington limestone, Cooper County, Missouri.

Cribroblastus schucherti n. s.

Plate V., Fig. 8, 8a.

Body globose, about as broad as long. It is one of the smallest species known. Basal portion very small and depressed. Fork pieces narrow, with a narrow sinus for the reception of the ambulacrum extending almost the whole length of the piece. Margins of the sinus drawn out to form a prominent crest on both sides of the ambulacrum, thus causing the interambulacral space to be slightly concave. Deltoids small, the upper portion running out to a small projecting spine. Summit openings, *i. e.*, mouth, anus and genital openings, twelve in number and not confluent.

This species, which resembles *C. cornutus* Meek and Worthen, differs from it, however, in the following characters: The base is not depressed as much, the margins of the ambulacral sini are less prominent, and the interambulacral spaces are not excavated as much as in *C. cornutus*. The interambulacra are twice as wide as in *C. cornutus*, in which species the interambulacra are about as wide as the ambulacra. The spiny projection is not as long or as prominent as in *C. cornutus*. Besides the foregoing differences the surface ornamentation is different in the two species, being granular in *C. cornutus*, and finely striated in the species under consideration.

Geological formation and locality: Subcarboniferous. Divide between Ross Fork and Lincoln Valley, Montana. The specimens were collected by Hayden's party, and first mentioned in the Annual Report for 1872, page 470, under the name *Pentremites bradleyi*, Meek. Types in the Smithsonian Collection, numbered 24,529. By close examination it was found that the specimens under this number consisted of two different species, one of these I have here named in honor of my friend, C. Schuchert.

Saccoblastus ventricosus, n. s.

Plate IV., Fig. 7.

Body bipyramidal. Base cup-shaped, with three characteristic impressions peculiar to this genus. Articulation surface of the column triangular. Column triangular. Ambulacrum very narrow, linear and sunk into the very prominent ambulacral sinus. Interambulacrum smooth and dipping a little toward the fork piece suture. Genital openings near the summit, not confluent, the oblique opening giving a slit-like appearance to them. Anal opening $\frac{1}{8}$ inch below the summit. Poral openings 11 to $\frac{1}{8}$ inch. The greatest transverse diameter is at the apex of the ambulacrum, which is about $\frac{2}{5}$ below the summit. Vertical diameter $\frac{7}{8}$ and the transverse diameter about $\frac{5}{8}$ of an inch.

Geological formation and locality: Warsaw limestone, Boonville, Missouri.

Globoblastus magnificus n. s.

Plate III., Fig. 5.

This specimen, although only a silicious cast, differs so much from all other known species, that I am thoroughly convinced of its specific value. It is nearly twice as large as an ordinary *G. norwoodi*, from which it is readily separated by the following characteristics. The base, though small, is not depressed, as in *G. norwoodi*. Fork pieces resemble those of *G. norwoodi*, but are larger and reach nearly to the summit of the calyx. The sinus of the ambulacrum is very narrow, extending, as in *G. norwoodi*, nearly the whole length of the ambulacrum.

Deltoids, to judge by the impressions of the suture markings, are perforated as in *G. norwoodi*. This is shown plainly on a small part of a deltoid piece remaining in the cast, which leaves no doubt as to its generic affinities. Interambulacral spaces seem to be more rounded and convex than in *G. norwoodi*. External ornamentation not known. Ambulacra narrow and seemingly extending over the whole surface as in the true *norwoodi*. The main differences, beside the size, between this species and *G. norwoodi*, are the shallow depression or almost flat basal plates and the more rounded interambulacral spaces, and, probably, a different external ornamentation.

Geological formation and locality: In a chert rock belonging to the same age as the Burlington limestone, in the southwestern portion of Missouri, near the Arkansas boundary line. Height of specimen, $1\frac{1}{8}$ inch. Width, 1 inch.

Globoblastus ornatus n. s.

Plate V., Fig. 4.

Body elliptical, longer than wide. Basals very small and depressed. Ambulacrum narrow and linear, extending the whole length of the body. Interambulacral space slightly rounded, wider in the center than near the base where it is rather depressed with little spine-like projections at the base of the sinus for the apex of the ambulacrum. The whole interambulacral space has an outer granulated margin, whereas the inner surface is ornamented by granulations shaped like an elongated spear head. Deltoids very small, with a horn-like projection above the summit and perforated in the center. This species is also easily recognized by the ornamentation of its interambulacrum.

Geological position and locality: It occurs in the Burlington limestone at various places in Missouri.

Globoblastus spathatus n. s.

Plate V., Fig. 5.

Body globose, resembling somewhat *G. norwoodi* in outline. Vertical and transverse diameters equal. Ambulacrum narrow and linear extending over the whole length of the body. Interambulacral space flat, ornamented at the outer margin by a row of granulations running down on each side of the fork piece sutures, giving in this manner a double row of granules in the center of each interambulacrum. Each interambulacral half so marked is ornamented by granulations in the form of a spatula. Deltoids small and protuberant, perforated in the center. The peculiar ornamentation of the interambulacral space is sufficient to separate it at once from allied forms.

Geological position and locality: It occurs in the Burlington limestone at Allenton, St. Louis County, Missouri.

Cribroblastus tenuis n. s.

Plate V., Fig. 17, 17a.

Body small, cylindrical, about twice as long as wide. Ambulacra extending almost over the whole surface of the body. Interambulacra rather convex with a marked crest in the center. The sutures where the forkpieces meet present a fine furrow as well as the sutures between the fork and deltoid pieces, whose external surface is finely granulated and occupies about one-fifth of the entire length of the body. The rest of the interambulacrum is transversely striated at both sides of the central crest. Genital openings very small, and not confluent. Basal part small and flat, visible externally only the thickness of the shell.

It is easily distinguished from *Cribroblastus roemeri* and *sampsoni* by its more slender form and by the external ornamentation.

Geological position and locality: Chouteau limestone, Pettis County, Missouri.

Induced by the sweeping statement of Mr. F. A. Bather, I give the following list, comparing the Blastoids in my collection with those of the British Museum. According to Mr. Bather's statement, p. x., Introduction to his Catalogue, the collection contained then (1899) 1,223 specimens. Quoting his remarks: "These figures speak for themselves. However numerous may be the specimens of Blastoidea in other museums, there can scarcely be any collection so representative of the class as a whole or as rich in specimens of the highest scientific importance as is that of the British Museum." This is a strong expression, especially since Mr. Bather has not seen all collections. Considering that America contains the bulk of the material, although admitting that the British Museum has the very valuable collections of Gilbertson, I. Rofe and L. G. de Koninck of unique specimens, I venture to say that our American material is on the whole better preserved than that found in Europe, and being confident that the American collectors did not send their best specimens across the water, it is not very doubtful to say that, for the study of this particular class of fossils, the best material is found on this side of the water. Comparing the figures of the British collection with my own, shows at a glance on which side the most material is to be found. Aside from this, my collection, which was brought together in fifty years, and comprises about ten thousand specimens, contains a number of real scientific specimens (pathologic and abnormal developments and specimens illustrating morphology) hardly to be found in any other collection. A student could learn more on a dozen or two picked specimens from our material than from the whole collection of Gilbertson, Rofe or de Koninck. Besides specimens illustrating the morphology, my collection contains considerably over one hundred pathologic and abnormal specimens.

I give the names as arranged in Bather's Catalogue, and an asterisk denotes the type specimen.

Br. M. stands for British Museum and H. for Hambach.

	Br. M.	H.
Codaster acutus	o	o
" canadensis		o
" gracilis	o	o
* " kentuckyensis		o
" pulchellus		o
* " pyramidatus	o	o
" trilobatus	o	o
*Codonites campanulatus	o	o
" conicus		
" fusiformis	o	o
" gracilis		o
" stelliformis	o	o
*Cryptoblastus kirkwoodensis		o
" melo	o	o
" pisum		o
" projectus		o
Cryptoschisma schulzi	o	o
Eleutherocrinus cassedayi	o	o
Granatocrinus cornutus		o
" curtus		o
" campanulatus	o	
" derbiensis	o	o
" ellipticus	o	o
" exiguus	o	

	Br. M.	H.
Granatocrinus glaber		o
" granulatus		o
" maccoyi	o	
" norwoodi	o	o
" orbicularis	o	
* " roemeri		o
Heteroblastus cumberlandi	o	
Mesoblastus angulatus	o	
" crenulatus	o	o
" elongatus	o	
" rofei	o	
" shumardi		o
" sowerbyi	o	
Metablastus bipyramidalis		o
" cottaldi	o	
" hispanicus	o	
" lineatus	o	o
" varsouviensis	o	o
" wachsmuthi		o
" wortheni	o	o
Nucleocrinus angularis	o	o
" elegans	o	o
" greenei		o
" lucina	o	
" meloniformis		o
" obovatus	o	o
" verneuili	o	o
" " var. pomum	o	o
Orophocrinus orbignyanus		o
" pentangularis	o	
" verus	o	
*Pentremites abbreviatus		o
" angularis	o	o
* " basilaris		o
* " bradleyi		o
* " broadheadi		o
" burlingtonensis	o	o
" cervinus		o
* " chesterensis		o
* " clavatus		o
" conoideus	o	o
* " decussatus		o
" eifeliensis	o	o
" elegans	o	o
* " elongatus	o	o
" florealis	o	o
* " gemmiformis		o
" godoni	o	o
" granulosus	o	o

		Br. M.	H.
*Pentremites	grosvenori		o
* "	hemisphericus		o
* "	nodosus		o
"	obesus	o	o
"	obliquatus	o	o
"	pailletti	o	o
"	pyriformis	o	o
* "	potteri		o
"	reinwardtii		o
"	robustus	o	o
* "	sampsoni	o	o
"	sayi	o	o
* "	spinosus		o
"	sulcatus	o	o
"	troosti	o	o
"	" var. symmetricus	o	o
Pentremitidea	americana		o
"	angulata	o	
"	clavata	o	o
"	gilbertsoni	o	
"	lusitanica	o	
"	malladai	o	
"	pailletti	o	o
"	similis	o	
"	wachsmuthi	o	
"	whidbornei	o	
Phaenoschisma	acutum	o	
"	archiaci	o	
"	benniei	o	
"	caryophyllatum	o	o
"	nobile	o	
"	verneuili	o	
Schizoblastus	melonoides	o	o
"	neglectus		o
"	shumardi		o
Tricoelocrinus	leei	o	
	meekianus	o	
	woodmani	o	o
Zygocrinus	benniei	o	
	tetragonus	o	
*Pentremites	angustus		o
* "	kirki		o
* "	obtusus		o
* "	rusticus		o
* "	serratus		o
* "	turbinatus		o
* "	tulipaformis		o
*Cribroblastus	incisus		o
* "	Schucherti		o

	Br. M.	H.
*Cribroblastus tenuistriatus		o
* " tenuis		o
* " verrucosus		o
*Saccoblastus ventricosus		o
*Cidaroblastus parvus		o
*Globoblastus magnificus		o
* " ornatus		o
* " spathatus		o

Issued November 4, 1903.

Plate I.

All figures are of *Pentremites sulcatus* and are from photographs of specimens in the author's collection: enlarged two diameters.

1. An ambulacrum, showing a sigmoid flexure in the ambulacral integument.

2. Summit view, showing distortion of the openings caused by lateral pressure.

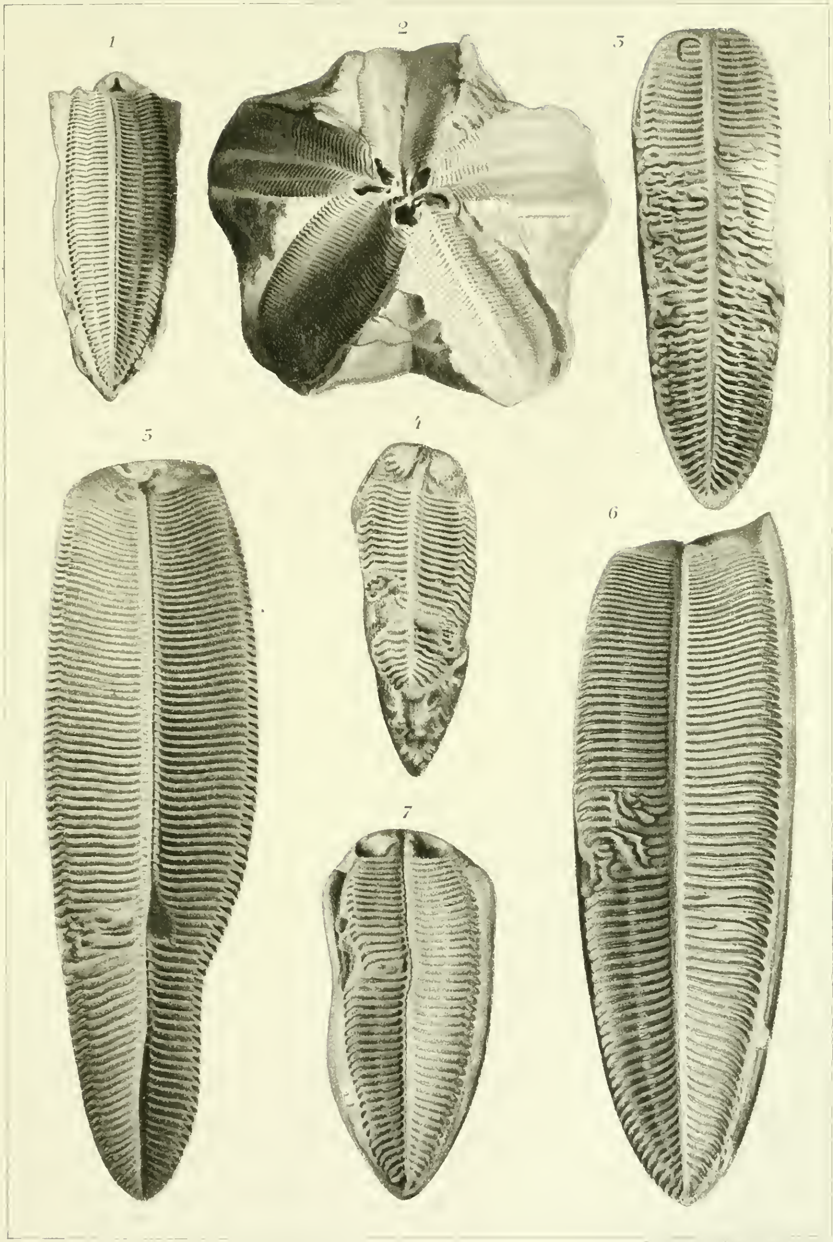
3. An ambulacrum, showing an extensive mechanical injury.

4. An ambulacrum, showing destruction and subsequent restoration of the apex.

5. Showing an injury in the upper third and the subsequent healing, and the loss of the poral pieces on the opposite side.

6. Scar of mechanical injuries on both sides of the field.

7. A similar injury, on one side of the field.



BLASTOIDEAE.

Plate II.

From specimens in the author's collection.

1. Upper view of a section of a row of poral pieces, showing collapsed tentacles in the poral openings.

2. Normal condition of the ambulacral integument.

3. Plications of integument covered by little scales, the larger scales at the summit standing upright.

4. Section through a row of poral pieces, showing the tentacles expanded.

5. View of the normal condition of the ambulacral integument.

6. Longitudinal section through the ovarian tubes.

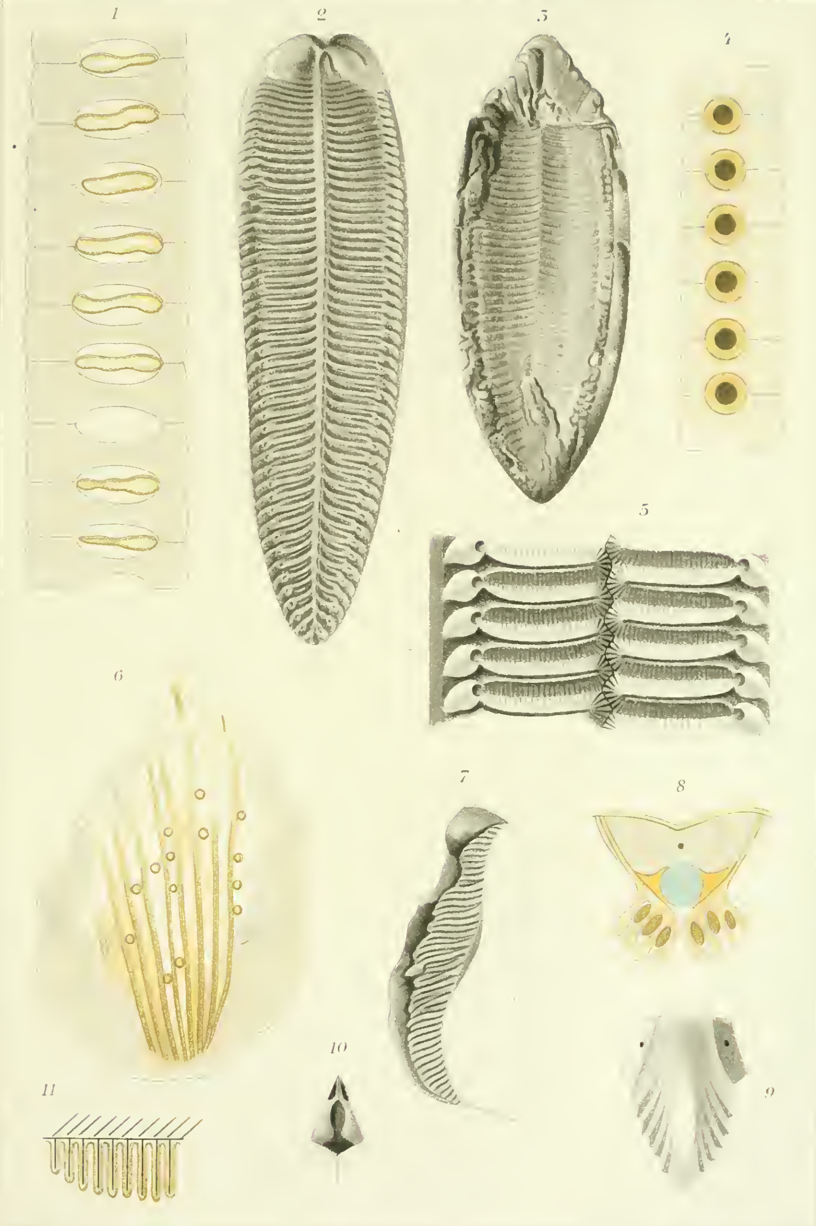
7. Irregular expansion of the integument.

8. Transverse section through an ambulacrum, showing lancet piece with the nervous channel, poral piece, vascular duct (blue), hydrospiric tube with its internal plications, and between them the ovarian tubes. The space at either side of the vascular duct, colored yellow, was filled with a clayey substance.

9. Base portion of the deltoid piece with the lateral expansion removed to show the grooves in which the hydrospiric plications rest: also the lateral orifices of the nervous channel.

10. Highly magnified view of the anal opening of *Saccoblastus*.

11. Section showing the looping of the hydrospiric membrane on the inner side of the calyx.



BLASTOIDEAE

Plate III.

From specimens in the author's collection, unless otherwise stated.

1. *Cidaroblastus granularis*, — loaned by G. K. Green.

2. Lateral view of same species, — Troost Collection, Smithsonian Institution, No. 33080.

3. Summit view of same.

4. *Cidaroblastus globosus*, — Troost Collection, Smithsonian Institution, No. 33077.

5. *Globoblastus magnificus.*

6, 7. Lateral and basal views of *Pentremites sulcatus*, showing an elongated piece inserted between two fork pieces.

8, 9. *Pentremites pyriformis*, showing an undeveloped fork piece and ambulacrum.

10. *Pentremites sulcatus*, showing a crippled ambulacrum.

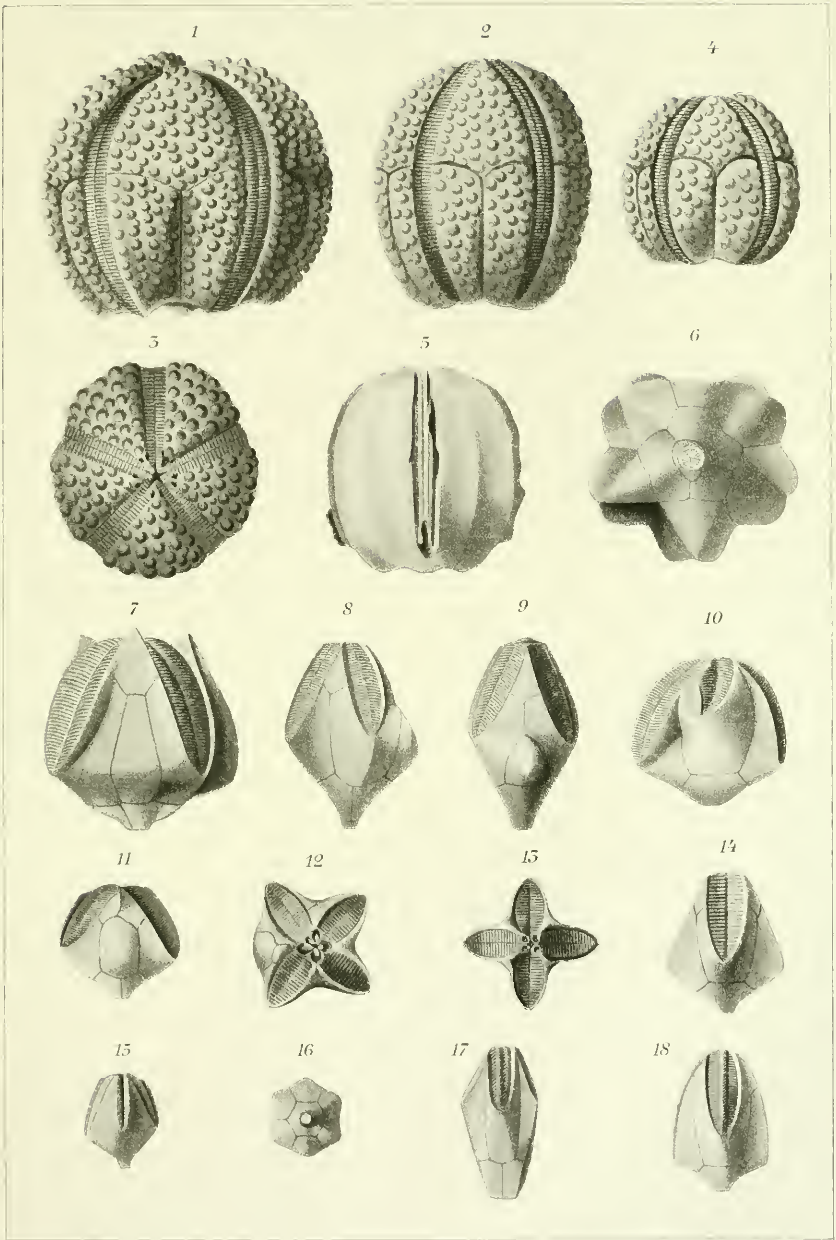
11, 12. *Pentremites sulcatus*, with only four ambulacra developed and a fifth fork piece solid.

13, 14. *Pentremites sulcatus*, with only four ambulacra.

15, 16. *Pentremites pyriformis*, with six fork pieces but only four ambulacra developed.

17. *Saccoblastus*, with five fork pieces but six ambulacra, of which two occupy one sinus.

18. *Pentremites godoni*, with four fork pieces but with five ambulacra, of which two occupy one sinus.



BLASTOIDEAE.

Plate IV.

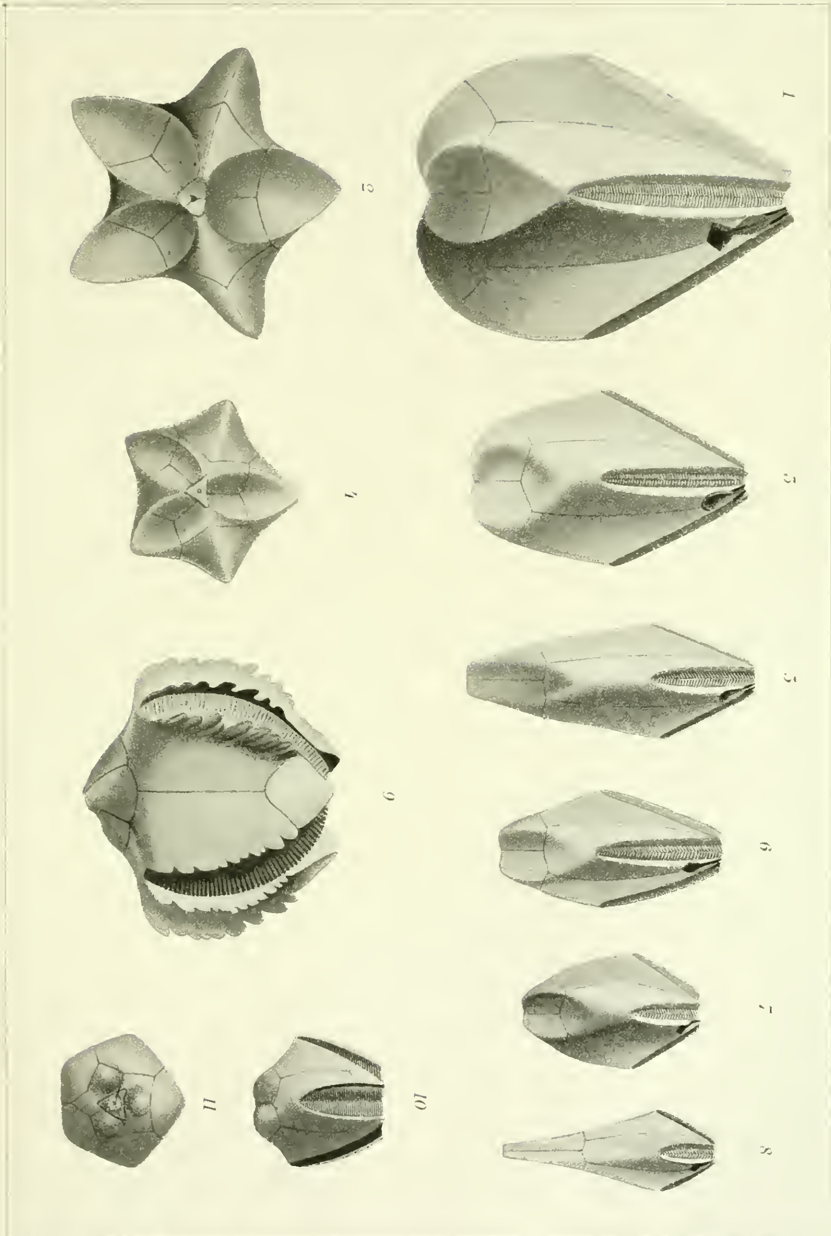
From specimens in the author's collection.

1. *Saccoblastus woodmani*, lateral view.
2. Same, base view.
3. *Saccoblastus obliquatus*, lateral view.
4. Same, base view.
5. *Saccoblastus wortheni*, lateral view.
6. *Saccoblastus pyramidalis*, lateral view.
7. *Saccoblastus ventricosus*, n. s., lateral view.
8. *Saccoblastus lineatus*, lateral view.

This row of figures shows the gradual development from one species to the other.

9. *Pentremites serratus*, from Ste. Genevieve, Mo.

10, 11. *Pentremites tulipaformis*, n. s., lateral and basal views.



BLASTOIDEAE.

Plate V.

From specimens in the author's collection, unless otherwise noted.

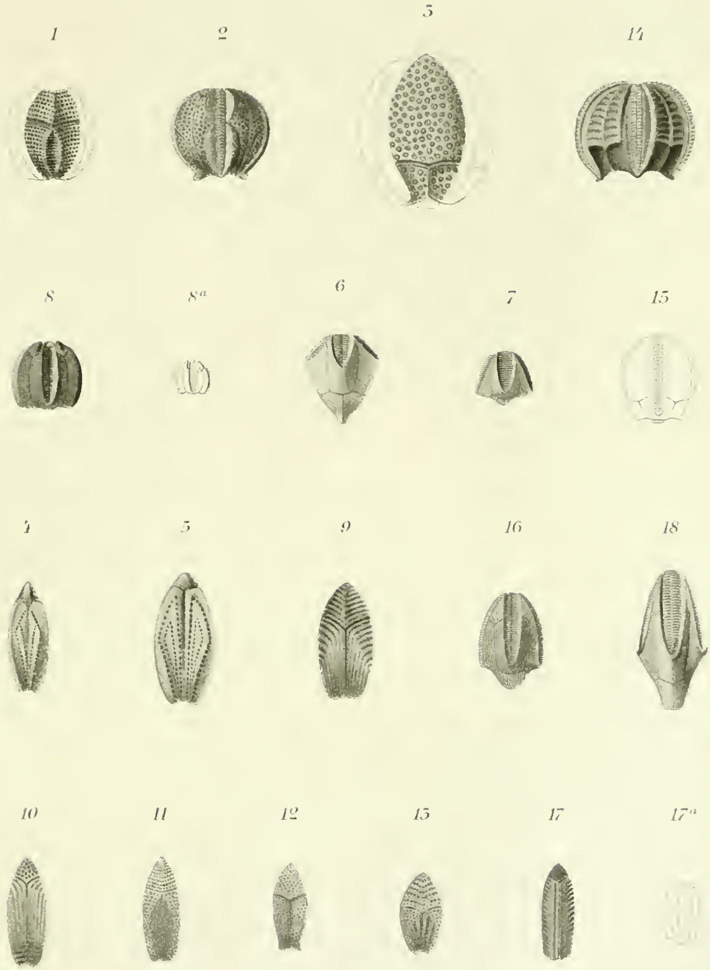
1. *Cidaroblastus parvus*, n. s., showing one interambulacrum.
2. *Cribroblastus incisus*, n. s.
3. *Cribroblastus verrucosus*, n. s., showing the interambulacrum.
4. *Globoblastus ornatus*, n. s., showing interambulacral space.
5. Interambulacrum of *Globoblastus spatatus*, n. s.
6. *Pentremites turbinatus*, n. s., lateral view.
7. *Pentremites bradleyi* Meek, — from specimen in the Smithsonian Institution.
8. *Cribroblastus schucherti*, n. s., magnified, — from specimen in the Smithsonian Institution.

8a. The same specimen, natural size.

9. Interambulacrum of *Cribroblastus sampsoni*.
10. Interambulacrum of *Cribroblastus Roemeri*.
11. Interambulacral space of *Cribroblastus neglectus*.
12. Interambulacral space of *Cribroblastus granulosus*.
13. Interambulacrum of *Cribroblastus pisum*.
14. *Cribroblastus sayi*, — from Shumard's type specimen.
15. Outline of *Cribroblastus potteri*.
16. *Cribroblastus tenuistriatus*, n. s.
17. Interambulacrum of *Cribroblastus tenuis*, n. s.

17a. Outline of specimen, natural size.

18. *Pentremites kirki*, n. s., lateral view, — from specimen in the collection of Mr. Kirk.

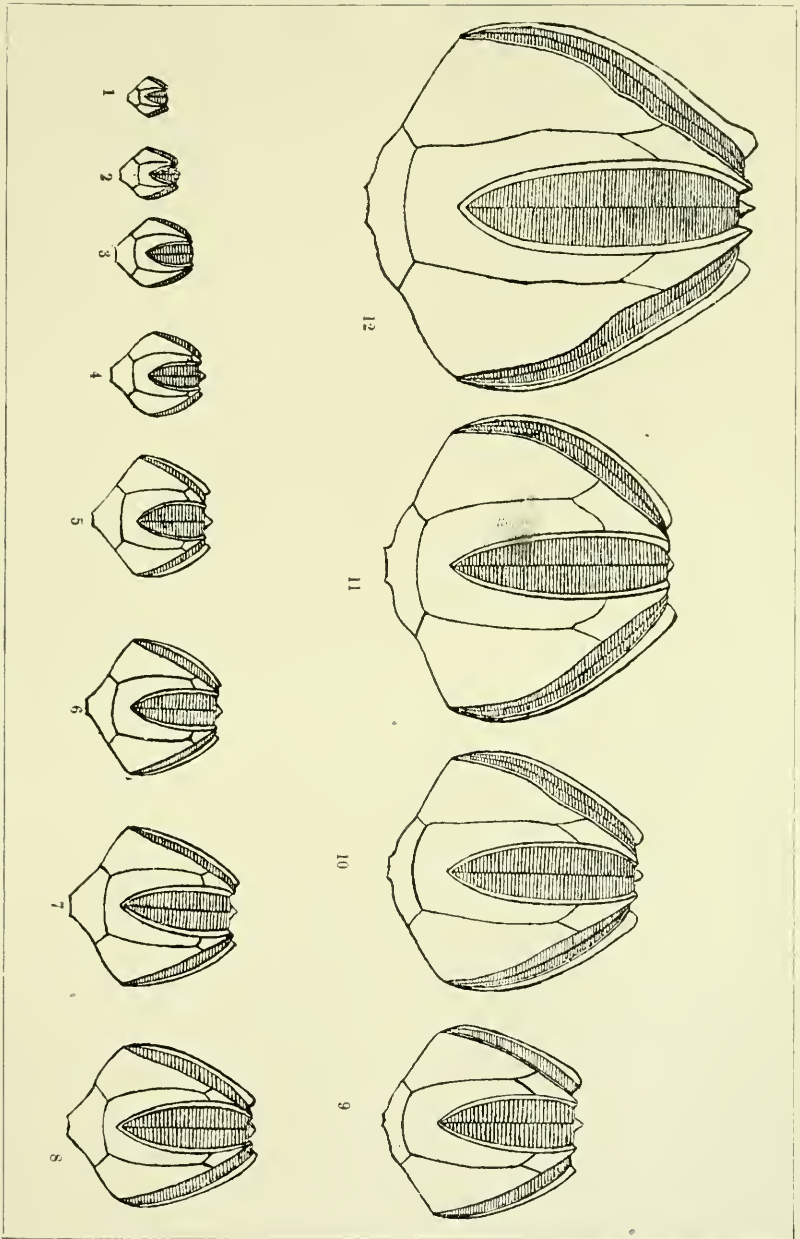


BLASTOIDEAE.

Plate VI.

From specimens in the author's collection.

A row of *Pentremites sulcatus*, showing the gradual development of the lateral expansion of the deltoids, which in Figs. 1–3 are not visible externally. All of the specimens are from the same locality.



BLASTOIDEAE.

PUBLICATIONS.

The following publications of the Academy are offered for sale at the net prices indicated. Applications should be addressed to The Librarian, The Academy of Science of St. Louis, St. Louis, Mo.

TRANSACTIONS (in octavo).

Vol.	Number.	Price per number.	Price per vol.	Price in set.
1	1* 2† 3, 4	.... $4.00 2.00 each.	$7.50 (Nos. 2-4 only.)	$7.00 (Nos. 2-4 only.)
2	1 to 3	2.00 each.	5.50	5.00
3	1 to 4	2.00 each.	7.50	7.00
4	1 to 4	2.00 each.	7.50	7.00
5	1-2, 3-4	4.00 each. (double numbers)	7.50	7.00
6‡	1, 2, 6, 8, 10, 11, 16, 17 4, 5, 7, 13, 14, 15, 18 3, 9 12	25 cts. each. 50 cts. each. 75 cts. each. $1.00	7.50	7.00
7‡	2, 3, 4, 6, 7, 8, 13, 15, 16, 18, 19 5, 9 to 12, 14, 20 17 1	25 cts. each. 50 cts. each. 75 cts. $1.00	7.50	7.00
8‡	1, 3 to 6 8, 10, 12 2, 7, 9, 11	25 cts. each. 50 cts. each.	3.75	3.50
9‡	1, 3, 4, 7, 9 2, 5, 8 6	25 cts. each. 50 cts. each. $1.25	3.75	3.50
10‡	9 2, 4, 5, 10 1 3, 6, 7, 8, 11	10 cts. 25 cts. each. 40 cts. 50 cts. each.	3.75	3.50
11‡	2, 3 5-8, 10, 11 1 4 9	15 cts. each. 25 cts. each. 45 cts. 75 cts. 1.00	3.75	3.50
12‡	1, 9, 10 5 3, 8 2, 4, 6, 7	25 cts. each. 30 cts. 35 cts. each. 50 cts. each.	3.75	3.50

MEMOIRS (in quarto).

Contributions to the archaeology of Missouri, by the Archaeological Section. Part I. Pottery. 1880. $2.00.

The total eclipse of the sun, January 1, 1889. A report of the observations made by the Washington University Eclipse Party, at Norman, California. 1891. $2.00.

---

* Supply exhausted.

† Can be sold only to purchasers of the entire volume,— so far as this can be supplied.

‡ Each number is a brochure containing one complete paper (or rarely two).

Transactions of The Academy of Science of St. Louis.

VOL. XIII. No. 2.

ON THE PREDETERMINATION OF THE SPEED OF THE TROTTING HORSE.

FRANCIS E. NIPHER.

Issued July 9, 1903.

ON THE PREDETERMINATION OF THE SPEED OF THE TROTTING HORSE.

Francis E. Nipher.

In a paper published in 1883 in the Transactions of The Academy of Science of St. Louis, the writer gave a discussion of numerical data covering the performance of all trotting horses making public records, between the years 1843 and 1883. The equation which gives the speed of the best horse at any date as function of the time, counted from any assumed date, was then published. It was found that the speed of the horse was approaching a limit, which was approximately that of the running horse. The limiting speed indicated by the data was 1:38, or 98 seconds to the mile. This was somewhat below the speed of the running horse, on an oval track, and it is evident that a limit of 100 seconds to the mile will also fit the observations in a very satisfactory way. The equation published in 1883 was

$$s = a + b^{-kt}$$

Here s is the speed, in seconds per mile, t years after any assumed date. At this assumed date $t = 0$, and $s = a + b$. It is evident that a is the limiting speed reached in an infinite time, and that b is the difference between the limiting speed, and the speed at the assumed zero date.

Mr. W. H. Pickering offered some criticisms on the method of obtaining the constants in the above equation, as it appeared in a preliminary form,* and in an appendix to the paper in the Transactions,† a slightly different method was employed. The constants so determined were

$$s = 98 + 43.5\epsilon^{-0.0127t}$$

$$\text{or} \quad \log\,(s - 98) = 1.637 - 0.0055t,$$

* American Journal of Science. III. **26**: 20–24. July, 1883.

† Trans. Acad. of Science of St. Louis. Vol. IV. No. 3, pp. 514–5. 1883.

where t is measured in years from 1860. According to this equation the speed of the trotting horse in 1903 would be obtained by making $t = 43$. The value so computed is $s = 123.1$ or two minutes and three seconds per mile (2:03).

The date when the two-minute horse will appear is found by making $s = 120$. The corresponding value of t is 54. The date is therefore $1860 + 54 = 1914$. These two results do not at present seem very far from the mark.

If in the above equation s be made 180, the date when the three-minute horse appeared is found to correspond to $t = -50$. The date is 1810. As a matter of fact the date when the three-minute horse appeared was, as I am informed, 1818, in response to a bet of a thousand dollars that no such horse could be produced.

Nearly all of the fast trotters belong to a few families. A very large per cent. have descended from Rysdyk's *Hambletonian*, foaled 1849, and *Mambrino Chief*, foaled 1844, both of whom were descended from the thoroughbred *Mambrino*. It would therefore be unreasonable to expect a very close agreement between observed speeds, of a century ago, and those computed from the above formula.

If in the equation, s be made 99, the time when the horse will have reached within one second of his limiting speed, is found to be 298 years after 1860.

The data from which the above equation was deduced were published in the American Journal of Science for April, 1883, by Professor Brewer, of Yale. The data covered all known official trotting records between the dates 1843 and 1883. From 1854 to the present time the speed of the trotter has increased from $s = 145$ to $s = 123$. This is a change of 22 seconds in the time of trotting a mile. According to the equation as shown above, it will take 255 years, or until the year 2158 to change the speed by 24 seconds more. In all time thereafter, the speed will be practically constant, as the speed of the running horse is now.

In 1892 when *Nancy Hanks* lowered the trotting record, the writer applied the above equation to her standard track record as published at that time, and covering the four years 1889 to 1892 inclusive. Estimating t in years from 1889, the equation for her performance was found to be

$$s = 124.5 + 20.0\epsilon^{-0.693t}$$

The constants in this equation were computed from the observed and published values reproduced in columns one, two and three of the following table. Column four shows the corresponding values of s computed from the last equation. The agreement between observed and computed values could not be more precise.

NANCY HANKS. STANDARD TRACK RECORDS.

t	Date.	s Obs.	s. Calc.	Diffs.
0	1889	144.5	144.5	0.0
1	1890	134.5	134.5	0.0
2	1891	129.5	129.5	0.0
3	1892	127.25	127.0	0.25
4	1893	——	125.7	—
5	1894	——	125.1	—
∞	——	——	124.5	—

The computed speeds for the years 1893 and 1894 are also given, and the limiting speed which this horse would make after an infinite time (if she could have continued to train indefinitely) is also given at the bottom of column four. It will be seen that this horse must have reached within one second of her own possible speed during 1893. In about four years the speed of this horse changed 19 seconds and came within one second of the final speed possible, even if this horse had been immortal and could have continued the process forever.*

* In September, 1892, this horse trotted a mile in 2:04, but this record was made with the newly adopted 28-inch wheel, with pneumatic tire and ball bearings. It is thought that this diminishes the time by about three seconds. I also find on examination that the record 2:07.25 in the table above was made with the same running gear. This makes the record for that year of less weight, in discussing the records of this particular horse.

In 1865 *Goldsmith Maid* began her career as a trotter, at the age of eight years. In the nine years which followed, her speed steadily increased, and is represented by the equation

$$s = 131.0 + 13.5\epsilon^{-0.193t}.$$

Her track record for this period is given in the following table, and the speed computed from the last equation is given in the fourth column of the table.

GOLDSMITH MAID. STANDARD TRACK RECORDS.

t	Date.	s Obs.	s Calc.	Diffs.
0	1865	146.0	151.0	+ 5.0
3	1868	141.5	142.2	+ 0.7
4	1869	140.5	140.2	— 0.3
6	1871	137.0	137.2	+ 0.2
7	1872	136.75	136.2	— 0.5
9	1874	134.0	134.5	+ 0.5

Another horse, *American Girl*, 1862, began her track record in 1867, and reached her best speed in 1874. Her change in speed is represented by the equation

$$s = 136.4 + 14.46\epsilon^{-0.707t}.$$

AMERICAN GIRL. STANDARD TRACK RECORDS.

t	Date.	s Obs.	s Calc.	Diffs.
0	1867	152.5	150.90	— 1.60
1	1868	144.0	143.53	— 0.47
2	1869	139.0	139.92	+ 0.92
4	1871	137.25	136.86	— 0.39
7	1874	136.5	137.43	+ 0.93

The last record that will be given is that of *Judge Fullerton*, 1865, whose track record covers the years 1871–5 inclusive.

His performance is represented by the equation

$$s = 137 + 7.94\epsilon^{-0.518t}.$$

A comparison of observed and computed values follows: —

JUDGE FULLERTON. STANDARD TRACK RECORDS.

t	Date.	s Obs.	s Calc.	Diffs.
0	1871	145.25	144.94	— 0.31
1	1872	141.75	141.73	— 0.02
2	1873	139.25	139.82	+ 0.57
3	1874	139.00	138.68	— 0.32
4	1875	138.00	138.00	0.00

It is evident that a slight change in the values of the constants, would in some cases make the agreement between observed and computed values somewhat closer. They are, however, very satisfactory, when we consider that the owners and drivers of these horses were not primarily seeking to secure accurate data for this discussion. It is evident also that the trainer's record would afford much more satisfactory material for a discussion of the subject, than can be realized in the track records. A record of three or four years might be expected to give a very fair idea of the future record of a horse.

In the original paper the date when any given speed originated, was obtained from the data of Brewer's table, by a discussion of the subsequent increase in the number of horses capable of that speed. For example in 1859 there was one horse who could trot a mile in 2 : 23 or better. In the next year there were two. Ten years later there were sixteen, and in 1882 there were 275. When these numbers were platted on a time axis, a logarithmic curve resulted. When the logarithm of the number of horses was similarly platted, a straight line was obtained. This straight line intersected the time axis at the date 1857, instead of 1859. This date for the origin of the speed 2 : 23 was considered much more weighty, than the date when some trotting match revealed the fact that the first horse capable of making this speed had already appeared. Horses who are by their owners known to be capable of breaking the record, are much more likely to be held back for advantageous conditions, than a horse of the same class would be after this speed has become a common one.

The effect of ball bearings, the pneumatic tire and the 28-inch wheel was to produce a sudden change in speed in 1892, but this is an effect that must and should be considered a part of the problem. The old high-wheeled sulky was also continually being improved, between 1850 and 1890. The interesting fact remains that the record to-day is within a second of that predicted twenty years ago.

The results here given also seem to be sufficient to establish another confirmation of a general principle of evolution. It would seem that each horse goes through during the few years of its track life, the same kind of evolution that its race goes through during the centuries. The same equation which represents the result of training the individual horse, represents also the supreme result of selection, breeding and training of the family.

Just as this paper is going to press, the world's record of the running horse has been lowered by *Alan-a-Dale*, to $s = 97.6$ (1 : 37.6). This, in connection with the well-known record of *Legal Tender* in 1865 and of *Ten Broeck* in 1887, will give the basis for a fair determination of the final limit of the running horse. The observed speeds are given in the following table: —

THE RUNNING HORSE. OVAL TRACK.

t	Date.	s Obs.	s Calc.	Diffs.
0	1865	104.0	104.0	0.0
22	1887	99.75	99.76	0.0
38	1903	97.6	97.6	0.0

The values of speed in the fourth column are computed from the equation

$$\log (s - 91.5) = 1.097 - 0.0082t$$

$$\text{or} \quad s = 91.5 + 12.5\epsilon^{-0.0189t}.$$

The differences between observed and computed values are certainly inside of the errors of observation. Only the three observations above given are known to me, but they are so far apart in time that they certainly give a fairly good determination. According to this equation, the limiting speed of the running horse on a standard track is 91.5 seconds to the mile (1:31.5). The speed of 1:32.5 will be reached when $t = 134$. This date is therefore ninety-six years from the present time. At this date, or in A. D. 1999, the running horse will be within one second of his final speed. The change in the time of running a mile during the next century will therefore be about six seconds. This result is something of a surprise. A previous knowledge of it would have caused me to somewhat modify certain passages in the present paper.

From the previous equations it will be seen that at the present time, the annual change in the time required to make one mile on a standard track, is for the running horse 0.12 sec., and for the trotting horse 0.29 sec.

Issued July 9, 1903.

PUBLICATIONS.

The following publications of the Academy are offered for sale at the net prices indicated. Applications should be addressed to The Librarian, The Academy of Science of St. Louis, St. Louis, Mo.

TRANSACTIONS (in octavo).

Vol.	Number.	Price per number.	Price per vol.	Price in set.
1	1*	....	$7.50 (Nos. 2-4 only.)	$7.00 (Nos. 2-4 only.)
	2†	$4.00		
	3, 4	2.00 each.		
2	1 to 3	2.00 each.	5.50	5.00
3	1 to 4	2.00 each.	7.50	7.00
4	1 to 4	2.00 each.	7.50	7.00
5	1–2, 3–4	4.00 each. (double numbers)	7.50	7.00
6‡	1, 2, 6, 8, 10, 11, 16, 17	25 cts. each.	7.50	7.00
	4, 5, 7, 13, 14, 15, 18	50 cts. each.		
	3, 9	75 cts. each.		
	12	$1.00		
7‡	2, 3, 4, 6, 7, 8, 13, 15, 16, 18, 19	25 cts. each.	7.50	7.00
	5, 9 to 12, 14, 20	50 cts. each.		
	17	75 cts.		
	1	$1.00		
8‡	1, 3 to 6, 8, 10, 12	25 cts. each.	3.75	3.50
	2, 7, 9, 11	50 cts. each.		
9‡	1, 3, 4, 7, 9	25 cts. each.	3.75	3.50
	2, 5, 8	50 cts. each.		
	6	$1.25		
10‡	9	10 cts.	3.75	3.50
	2, 4, 5, 10	25 cts. each.		
	1	40 cts.		
	3, 6, 7, 8, 11	50 cts. each.		
11‡	2, 3	15 cts. each.	3.75	3.50
	5–8, 10, 11	25 cts. each.		
	1	45 cts.		
	4	75 cts.		
	9	1.00		
12‡	1, 9, 10	25 cts. each.	3.75	3.50
	5	30 cts.		
	3, 8	35 cts. each.		
	2, 4, 6, 7	50 cts. each.		

MEMOIRS (in quarto).

Contributions to the archaeology of Missouri, by the Archaeological Section. Part I. Pottery. 1880. $2.00.

The total eclipse of the sun, January 1, 1889. A report of the observations made by the Washington University Eclipse Party, at Norman, California. 1891. $2.00.

* Supply exhausted.

† Can be sold only to purchasers of the entire volume,—so far as this can be supplied.

‡ Each number is a brochure containing one complete paper (or rarely two).

Transactions of The Academy of Science of St. Louis.

VOL. XIII. No. 3.

SECOND CONTRIBUTION TO THE HERPETOLOGY OF MISSOURI.

JULIUS HURTER.

Issued July 31, 1903.

SECOND CONTRIBUTION TO THE HERPETOLOGY OF MISSOURI.*

Julius Hurter.

In 1897 I had the honor to report on a number of reptiles and batrachians that I had ascertained to occur in the State of Missouri, and this evening I am able to add nineteen new species not before found nor reported for the State. But before I proceed let me give you an idea of the difficulty in finding co-workers in my line of collecting. Prof. H. M. Whelpley, editor of the *Meyer Brothers' Druggist*, had the kindness to distribute with that periodical a circular, asking for assistance in collecting and sending in specimens from their respective counties. This circular reached about 1,300 druggists in the State of Missouri, and in response to it I received fifteen answers from persons that would like to help; but to my great regret I found out that even they were more interested from a financial than from a scientific standpoint. This gives an idea how difficult it is to get assistance from outside parties in this particular branch of study. Still, I am under obligations to the following gentlemen who offered their services and procured me a good deal of material from their respective counties, viz.: J. H. Black, Esq., Newton County; J. C. Miles, Jasper County; J. M. Parker, Montgomery County; Prof. R. R. Rowley, Pike County; Fuller Smith, Clark County; Robt. Lotze, Oregon County; Dr. A. Schaffraneck, St. Charles County; George Miller of our city, who brought in quite a number of specimens from Stoddard County; also Mr. H. N. Force, Ozark County; Dr. J. R. Terry who collected in Adair County, and W. K. Smith, Crawford County. All of these gentlemen brought in valuable additions, which are mentioned in their proper places. The increase over my previous list consists of nineteen species as before mentioned, viz., six batrachia and thirteen reptilia.

* Presented to The Academy of Science of St. Louis, January 5, 1903.

Class BATRACHIA.

Order Urodela.
The Tailed Batrachians.

1. Amblystoma punctatum, L. — The spotted salamander.

This salamander when alive is one of our prettiest specimens, being of a dark bluish-black color with a number of yellowish-white shining spots on the back and abruptly light olivaceous underneath. The legs are of the color of the under parts, not of the upper. This animal is one of those that uses its tail as an organ of prehension. When taken up and held so that it expects to be dropped, it is its habit to take a hold of some support with the tail and if one is not found at once, the tail is moved about in search of an object that might answer this purpose.

It is mostly found under decaying logs in damp shady places, but is in no way plentiful: — Drake, St. Louis County, April 24; Butler County, April 16 and July 17; Stoddard County, October 26.

2. Hemidactylium scutatum, Tschudi. — The scaly salamander.

This is a small species. I copy the description from Cope's "Batrachia of North America," as one of the best: Back, dark chestnut, but above much lighter, both sprinkled with black, the latter more especially along the dorsal line. Snout above, eyes above and in certain lights the furrows above the lateral longitudinal lines light chestnut approaching to golden bronze, faintly clouded in spots with darker. Sides of body finely mottled brown and bluish-white. Head, body, and tail below, chalk white with a tinge of blue. Sparingly and irregularly marked with rather large black spots; spots disposed along sides and the white of tail beneath. Central tract unspotted. One or two furrows or constrictions go entirely around the tail behind the vent, marking the narrow base of the tail, which then swells abruptly in many specimens.

Neither the late Professor Cope nor the museum catalogue of the Smithsonian mentions the animal as being ever caught west of the Mississippi. I am under obligations to my friend Dr. George W. Bock, who found one specimen near Bourbon, Crawford County, October 15, 1899, and presented it to me.

3. Spelerpes maculicaudus Cope. — The western cave salamander.

In 1880 Professor E. D. Cope described this as a new salamander from a spring at Brookville, Indiana. This species has since been found to be the common cave salamander of the Mississippi Valley along with *Spelerpes longicaudus*. It is similar in build to the cave salamander, *Spelerpes longicaudus* and also to the next species, the newly discovered *Spelerpes stejnegeri*, but differs in color. All the specimens, old or young, are of a Chinese orange color in life and have the back and sides of the body, tail and limbs covered with sharply defined irregular rounded and elongated spots. It is a twilight species.

So far I have only found it in Jefferson County, in a small ravine, but it has been found also by other collectors at the mouth of Fisher's cave near Springfield, Green County; near Marble cave, Stone County; Rockhouse cave, Barry County; and Wilson's cave, near Sarcoxie, in Jasper County.

4. Spelerpes stejnegeri, Eigenmann.

The latest discovered species. I have not yet seen this species and therefore have to give the description from its discoverer, Professor Eigenmann: — The back is raw sienna with many spots, coalescing in places and irregularly arranged in two series on each side of the median line. The median line and a streak from the eye back to above the hind limbs are free from spots. Sides dark brown with irregular dots of marbling of sienna. The belly is clear.

This salamander has been found in Rockhouse cave, Barry County; near Marble cave, Stone County; Wilson's cave, Jasper County; and Fisher's cave, Green County: all in southwestern Missouri.

5. Typhlotriton Spelaeus Stejn. — Blind cave salamander of Missouri.

The first specimen of this salamander was collected by F. A. Sampson, of Sedalia, in Rockhouse cave, Barry County, and described by Dr. L. Stejneger of the National Museum. Afterwards Professor E. D. Cope found some in Marble cave, Stone County. It is rather a rare species. The color in life is pale flesh color. I have not yet been able to secure a specimen for my collection.

Order Salientia.
The Frogs.

1. Acris gryllus Le Conte. — The cricket frog.

I include it in my list because it is mentioned in Cope and Yarrow's list as No. 35601 of the Smithsonian collections: — six specimens from New Madrid County, collected by R. Kennicott, one of the pioneer collectors.

The best character to distinguish this frog from its western representative, *Acris gryllus crepitans*, is that in the former when the hind limb is carried forward along the side of the body, the tibio-tarsal articulation reaches to the tip of the snout or a little beyond, whereas in *crepitans* the same articulation hardly reaches to the tip of the snout. Also, *Acris gryllus* is the longer one of the two, measuring $1\frac{4}{10}$ inch, where *crepitans* reaches only $1\frac{2}{10}$ to $1\frac{1}{4}$ in. in length of body.

Class REPTILIA.

Order Chelonia.
The Turtles.

1. Chrysemys marginata Agassiz.

C. cinerea Brown.

A so-called painted turtle from the lively red markings on the edge of the carapace. This turtle is common in the lowlands across the Mississippi, in Illinois. Some specimens are found in the back-waters of this river on the Missouri side. The plastron in the adult is usually all blood red, hiding a large dull black mark that extends from near the gula on the center of the belly to the anals without any lateral branches as in *Chrysemys bellii.* The young are very different in the marking of the plastron from *Chrysemys marginata* of Indiana, Eastern Illinois, and Michigan. The shields of the plastron are alternately red and yellowish-white on each side of a dark center streak. This turtle is called by the fishermen "Red belly" and with right, as in spring nothing of the dark central mark of the plastron can be seen.

2. Chrysemys dorsalis Agz.

This is another rather scarce turtle that I have found in our most southeastern counties in the so-called "sunken lands." It is easily recognizable from a wide reddish streak along the center of the back. So far I have specimens from Butler County, May 1, 1898.

3. Pseudemys texana, Baur. — The Texas Cooter.

This turtle has gone so far under the name *Pseudemys concinna*, Le Conte. Le Conte says it inhabits the rivers of Georgia and Carolina. I have never seen it below Augusta on the Savannah or Columbia on the Congaree; we have therefore to consider specimens from these localities as typical. The species is characterized by its broad and low shell and its small head.

Dr. Baur considers *Pseudemys texana* as the representative of *Pseudemys* in the southern portion of the country west of the Mississippi: — Texas, Indian Territory, Northern Mexico, Missouri. Professor Agassiz mentions in his monograph on turtles some that were collected by Dr. Roy, in Southwestern Missouri. I have received two nice specimens, one from Mr. F. A. Black, from Newton County, and the other from Mr. J. Carroll Miles, from Carthage, Jasper County, where he collected it from the Spring River, which empties into the Neosho, a tributary of the Arkansas River. In 1895, when on a business trip to Paris, Texas, I collected there a very fine specimen, the carapace of which is a good deal higher than of any other I have seen so far.

4. Aromochelys tristycha Agz. — A musk turtle.

About a month ago Mr. H. N. Force, Ph. G., sent me quite a collection of reptiles from Ozark County, and amongst them I found one half-grown specimen of this variety. Professor Louis Agassiz, in his monograph on turtles, 1857, mentions specimens that were sent to him by Mr. G. Stolley from the Osage River, in Missouri. Agassiz writes: "Although *Ozotheca odorata*, its eastern congener, varies greatly not only in color but even in outline, I have no doubt that this is a distinct species characterized when young by the great prominence of the keels upon the vertebral and costal plates and by numerous dark dots between the scales of the sternum, and when adult by a marked difference in the form of the snout. In *Ozotheca odorata* the snout is much more prominent on account of the slope of the upper jaw, which extends further back and is therefore less steep than in *O. tristycha*, the lower jaw of which is broader below the symphysis than in *odorata*, and suddenly turned up."

Order Squamata.

Suborder Sauria.

Lizards.

Iguanidae.

1. Phrynosoma cornutum Harlan. — Commonly called "horned toad."

Mr. H. Q. Taylor, a resident of St. Louis, informed me that he captured a specimen on the sandy river shore opposite Leavenworth, in Missouri. Through advertising in the papers, I received letters from gentlemen stating that this animal had been caught in the streets of their respective places but all these seem to have been escaped specimens and were thus caught. The only authentic record of this lizard, as occurring in the State, I find in the United States National Museum reports by Dr. E. D. Cope, Crocodilians, Lizards and Snakes of North America, on page 436 under No. 17397–99:— three specimens collected by C. W. Richmond in Southwestern Missouri.

Suborder Ophidia.
Snakes.
Poisonous Snakes.

1. Sistrurus miliarius Linn. — Ground rattlesnake.

It gives me pleasure to bring to notice another pit viper, that has been caught by my friend Mr. Rob. Lotze in Oregon County. He was not aware that he had killed a poisonous snake. On an inquiry he wrote me that he captured it from under some debris of an old shanty on the slope of a hill. This specimen looks more similar to those from Texas than to some from Alabama and Florida that are in my collection.

Harmless Snakes.

2. Farancia abacura Holbrook. — The so-called hoop snake or horn snake.

The color of this snake is bluish-black above. On the two outer rows the ground color assumes the shape of vertical bands, from one and a half to two scales broad, leaving an intermediate space from two to three scales wide, which is red in life. Both the red and bluish-black extend on the abdomen, the former being the ground color. The vertical bands of the flanks are confluent on the middle of the abdomen, either directly opposite or alternating.

My son Henry collected six specimens near Poplar Bluff, Butler County, April 24. The snake lives near the shores of stagnant waters and is generally found beneath dead logs and other objects.

3. Liopeltis vernalis DeKay. — The grass snake.

The scales of this little snake are smooth. It is dark green above, lighter on the flanks and yellowish-white beneath.

I received the only specimen that I have come across from Dr. A. Schaffraneck of St. Charles. The doctor caught it and two others in his garden. I have never encountered this snake in the last twenty years during which I have paid attention to the collecting of reptiles, and I am of the opinion that the Missouri river stops it from coming farther south in this region. I remember very plainly that about twenty-five years ago I caught and played with about ten or twelve specimens that I found at one spot on the side of a fence in Madison County, Ills. R. Kennicott also reports in the Smithsonian Catalogue, under number 2204, on a specimen that he collected in Monroe County, Ills. I think that cultivation has destroyed its haunts and more or less exterminated it.

4. Coluber vulpinus Baird and Girard. — The fox snake.

April 22 I found the first specimen of this snake at Dardenne prairie, St. Charles County. The same day I came across two other dead specimens that somebody had killed and mutilated. Mr. Charles Aldrich sent three specimens to the Smithsonian that he collected in Webster City, Iowa. Cope states that it is distributed over the northwest of the eastern district, not being known from east of Illinois, or south of the Missouri River. This is the most robust species of the genus and reaches as large a size as any.

5. Coluber spiloides, Dumeril and Bibron.

Professor Cope in his work "Crocodilians, Lizards and Snakes of North America," mentions on page 843 one specimen, under No. 5505 of the Smithsonian collections, as collected at Independence, Jackson County. The snake is of common occurrence in Texas and Indian Territory and should therefore be in our western counties. I have specimens only from Waco, Texas, in my collection.

6. Coluber guttatus Linnaeus. — The spotted racer.

For three years successively I have found a young specimen of this species near Pevely, Jefferson County, and curious to say they were found always under a small rock on the top of a large one, nearly at the same place. Last year my son had the good fortune to capture a fine adult specimen, but this time in the fields, though not far from the first place: — May 15, 1898; May 13, 1900; May 7, 1899; and May 26, 1901; the adult specimen.

7. Pityophis sayi Schlegel. — The bullsnake.

I have heard a good deal about this snake but never had the opportunity to capture one myself. Mr. Carroll Miles of Carthage, Jasper County, has sent me a fine living specimen. This snake was one of the most vicious snakes that I ever came across, and it may be accounted for, as Mr. Miles wrote me on inquiry that they had it for quite a while in the school where it was always teased to the utmost. This last fall Mr. Frank Schwarz gave me also a fine specimen that had been caught in the bluffs in St. Clair County, Ills., opposite the city of St. Louis.

8. Bascanion constrictor flaviventris Say. — The green racer.

From the same place, Jasper County, and from the same gentleman, I received a specimen of this western variety, and a year ago a second specimen from Mr. W. K. Smith of Cuba, Crawford County. The color of the back of this species is olive green, and the whole under-surface greenish-white to bright yellow.

9. Natrix cyclopium Baird and Girard. — Cyclope water-snake.

My son Henry found some of these in a small lake near Poplar Bluff, Butler County, May 19 and 22 and October 3, 1897. They are hard to catch as they always seek refuge in the deeper waters.

The late Professor Cope gives the following very good description of this snake: Color brown above, yellow below. On the upper surface there are on each side two rows of alternating short crossbars of a darker color, which are about one and one half scales wide, and are separated by interspaces of about three scales. The median line for a width of four scales is not spotted, or is very imperfectly so, forming a broad vertebral band of a color darker than the general ground. In young specimens the pattern is very distinctly seen; but in adults the ground becomes so dark as to obscure it very much. The head is uniform brown, the oral edge of the superior labial plates only being yellow. On the yellow ground of the inferior surfaces there appear, on the anterior third only of the length, dark shades on the anterior parts of the gastrosteges. These extend and blend so that on the posterior two-thirds of the length in the adult the color may be said to be blackish-brown with yellow spots. This well marked species is nearest to *Natrix rhombifera*, also found in the State.

The present contribution brings the number of Batrachians and Reptiles recorded as found in the State of Missouri to ninety-three, as follows: —

16 Tailed Batrachians.
13 Toads and frogs.
18 Turtles.
7 Lizards.
39 Snakes.

I do not doubt whatever that this list will in time reach one hundred and over, as there are quite a number of species of this class in northern Arkansas, Indian Territory and Kansas, that will eventually also be found in the State of Missouri.

Issued July 31, 1903.

PUBLICATIONS.

The following publications of the Academy are offered for sale at the net prices indicated. Applications should be addressed to The Librarian, The Academy of Science of St. Louis, St. Louis, Mo.

TRANSACTIONS (in octavo).

Vol.	Number.	Price per number.	Price per vol.	Price in set.
1	1* 2† 3, 4	.... $4.00 2.00 each.	$7.50 (Nos. 2-4 only.)	$7.00 (Nos. 2-4 only.)
2	1 to 3	2.00 each.	5.50	5.00
3	1 to 4	2.00 each.	7.50	7.00
4	1 to 4	2.00 each.	7.50	7.00
5	1-2, 3-4	4.00 each. (double numbers)	7.50	7.00
6‡	1, 2, 6, 8, 10, 11, 16, 17 4, 5, 7, 13, 14, 15, 18 3, 9 12	25 cts. each. 50 cts. each. 75 cts. each. $1.00	7.50	7.00
7‡	2, 3, 4, 6, 7, 8, 13, 15, 16, 18, 19 5, 9 to 12, 14, 20 17 1	25 cts. each. 50 cts. each. 75 cts. $1.00	7.50	7.00
8‡	1, 3 to 6 8, 10, 12 2, 7, 9, 11	25 cts. each. 50 cts. each.	3.75	3.50
9‡	1, 3, 4, 7, 9 2, 5, 8 6	25 cts. each. 50 cts. each. $1.25	3.75	3.50
10‡	9 2, 4, 5, 10 1 3, 6, 7, 8, 11	10 cts. 25 cts. each. 40 cts. 50 cts. each.	3.75	3.50
11‡	2, 3 5-8, 10, 11 1 4 9	15 cts. each. 25 cts. each. 45 cts. 75 cts. 1.00	3.75	3.50
12‡	1, 9, 10 5 3, 8 2, 4, 6, 7	25 cts. each. 30 cts. 35 cts. each. 50 cts. each.	3.75	3.50

MEMOIRS (in quarto).

Contributions to the archaeology of Missouri, by the Archaeological Section. Part I. Pottery. 1880. $2.00.

The total eclipse of the sun, January 1, 1889. A report of the observations made by the Washington University Eclipse Party, at Norman, California. 1891. $2.00.

---

* Supply exhausted.

† Can be sold only to purchasers of the entire volume,—so far as this can be supplied.

‡ Each number is a brochure containing one complete paper (or rarely two).

Transactions of The Academy of Science of St. Louis.

VOL. XIII. No. 4.

A BIRD'S-EYE VIEW OF THE LITERATURE OF ETHICAL SCIENCE SINCE THE TIME OF CHARLES DARWIN.

WALTER L. SHELDON.

Issued August 21, 1903.

A BIRD'S-EYE VIEW OF THE LITERATURE OF ETHICAL SCIENCE SINCE THE TIME OF CHARLES DARWIN.*

WALTER L. SHELDON.

In presenting this paper I am assuming that it is being offered to a body of men for the most part absorbed in a study of the physical sciences. Owing to the necessity nowadays for specializing, and to the effort required to keep up even with the literature in your own departments, it may be that some of you are not fully aware of what has been going on along those lines where the work is of a more subjective character. It struck me therefore that I might be doing a real service by giving you a hint as to the trend of the literature in the science of ethics for the last three or four decades, since the time of Darwin. It would be a satisfaction on my part to convince you that in this other direction good work has been going on, of as painstaking and thorough a character as anything which may have been done in physics, chemistry or biology. My purpose is not myself to criticise or theorize, but merely to sketch for you a bird's-eye view of the situation. Men of as great intellectual caliber as any of those at work in your special departments, have been grappling with the problems of ethical science; and they have achieved encouraging results, while these results may not be as great as some would have anticipated.

Although ethics has a large subjective element in it, most of the leading workers in this direction would regard it strictly as a science, and deal with it in that light. These men are undertaking to investigate a body of facts, to analyze them, to correlate them, to interpret them, and reduce them if possible to a system. Some of them would, however, regard

* Presented to The Academy of Science of St. Louis, January 19, 1903.

their department as more distinctively a "normative" science in contrast with the departments in which most of you are at work. A few of them may prefer to speak of their line of effort as "ethical philosophy." Among the Germans, it is almost universally customary to employ the term, "ethische Wissenschaft."

It is true, however, that there is not the same unanimity of opinion among the workers in this other direction, that we may find among yourselves. I am painfully conscious of this fact, and admit that it may be at first thought a little depressing. They cannot specify in precise language just what points have been established beyond dispute, nor can they say that this and this has been settled once for all by the latest investigations. Nevertheless there is some good explanation for these divergencies of opinion. In all frankness one may venture the assertion that the issues here are of more vital importance than they would be in those sciences in which most of you are absorbed. The honor of the human soul is at stake. There is here, therefore, a personal element involved, and one which must exert an enormous influence. No such factors are concerned in the decision of the question as to whether atoms or ether are realities, or only working hypotheses; whether the wave theory of light is beyond dispute; or as to the processes by which the living cell once got its start out of inorganic matter. The foundations of the world will not be shaken by any discoveries to be made in these other fields of research, great as the achievements may be.

But when it comes to a study of the nature and origin of conscience or of ethical ideals, one draws a deep breath of anxiety. The whole social structure in which you and I live and move and have our being is at stake. The sanctity of our home and family life is involved. We are then working at the foundation stones, and the hand that is chipping away at the block may tremble a little at the thought of what is going to fall.

I have chosen the time of Darwin and the publication of "The Descent of Man" as the dividing line, because since that time ethical science has gone through about as great a revolution or transformation as any of the other sciences. And the occasion for the change lay chiefly in the doctrine of evolution. It is not as if all this influence came simply from Charles Darwin. The new tendency of thought was arising, as we know, for a time previous to him and his publication. The whole subject was simply clinched at one point by his work. But when his theories were put forward in such a masterly way, all those sciences dealing more especially with subjective experiences were also profoundly concerned. Almost every student or worker in ethics felt called upon to give his theories a thorough overhauling, and to rewrite some of his statements or propositions. It really amounted to beginning over again or taking a new start.

But before the publication of "The Descent of Man" by Darwin, the change was rapidly going on. Herbert Spencer already had in his mind, as I understand, the outlines of his "Theory of Ethics," even before the appearance of "The Origin of Species" in 1859. During the '60's Alexander Bain published his "Mental and Moral Science," and undertook to tear away the traditions surrounding an "intuitional" conscience in order to explain it by an associational psychology. Lecky had taken up the historic movement and published his "History of European Morals from the Reign of Augustus to Charlemagne." Every man deeply concerned in these great problems felt in advance just what was coming, before the appearance of "The Descent of Man" in 1871. It was known that Conscience and the Ethical Ideal were to be at stake. The issue was all latent in the first work, "The Origin of Species." One had to expect that a leading chapter in the second work by Darwin would be on "The Origin of the Moral Sense," and the expectation was fulfilled.

In order to give you the merest glimpse of what has been going on, therefore, during this time from the year 1871 since the publication of "The Descent of Man," by Charles Darwin, it may be well for me to put before your eyes a list of the treatises dealing specifically with ethical science or ethical philosophy, which I happen to have in my private library.

Charles Darwin, — "The Descent of Man." — Chap. 4, Part 1......... 1871
Henry Calderwood, of the University of Edinburgh, Scotland. — "Handbook of Moral Philosophy."................................ 1872
Paul Janet, of the Sorbonne, Paris. — "Theory of Morals." — English Translation. — First edition in French, — "La Morale."···· 1873
Henry Sidgwick, of Cambridge, England.
(1) "The Methods of Ethics."................................ 1874
(2) "Outlines of the History of Ethics."........................ 1886
Edith Simcox, of England. — "Natural Law." — An Essay in Ethics. — Second edition.. 1878
Hermann Lotze, of the University of Berlin. — "Outlines of Practical Philosophy." — Short condensed treatise, translated from lectures delivered in.. 1878
Herbert Spencer, of England. — "The Principles of Ethics." — Two volumes..1879–1893
W. K. Clifford, of University College, London. — "Lectures and Essays." — Especially Volume II................................ 1879
Eduard von Hartmann, of Germany. — "Phänomenologie des sittlichen Bewusstseins.".. 1879
B. Carneri, of Vienna, Austria. — "Grundlegung der Ethik."........ 1881
Sir Leslie Stephen, of England. — "The Science of Ethics."......... 1882
Thomas Hill Green, of Oxford, England. — "Prolegomena to Ethics." 1883
H. Steinthal, of University of Berlin. — "Allgemeine Ethik."......... 1885
James Martineau, of Manchester New College, London. — "Types of Ethical Theory. — Two volumes................................ 1885
M. Guyau, of France. — "Esquisse d'une Morale sans Obligation ni Sanction.".. 1885
W. R. Sorley, of University College, Liverpool, England. — "The Ethics of Naturalism.".. 1885
Wilhelm Wundt, of the University of Leipsic. — "Ethik. — Eine Untersuchung der Thatsachen und Gesetze des sittlichen Lebens." 1886
Christoph Sigwart, of Germany. — "Vorfragen der Ethik." — A single lecture somewhat enlarged.. 1886
Rudolph von Jhering, of Germany. — "Der Zweck im Recht." — Two volumes.. 1886
Harald Höffding, of the Univerity of Copenhagen, Denmark. — "Ethik." — German translation from the first Danish edition 1887
J. G. Schurman, of Cornell University. — "Ethical Import of Darwinism.".. 1887
Friedrich Nietzsche, of Germany. — "A Genealogy of Morals." — English Translation from the German................................ 1887
G. von Gizycki, of the University of Berlin. — "Moralphilosopie."... 1888
Friedrich Paulsen, of the University of Berlin. — "System der Ethik.".. 1889
Hugo Münsterberg, of Germany, now of Harvard University. — "Der Ursprung der Sittlichkeit." — A single lecture somewhat enlarged.. 1889
Wilhelm Schmidt, Pfarrer in Cuertow, Germany. — "Das Gewissen.".. 1889
Franz Brentano, of Germany. — "Vom Ursprung sittlicher Erkenntnis.".. 1889

Paul Hensel, of the University of Strassburg. — "Ethisches Wissen und ethisches Handeln." — A short treatise or single lecture..... 1889

William MacEntyre Salter, of the Society for Ethical Culture, Chicago.— "Ethical Religion."— A collection of lectures on miscellaneous subjects.. 1889

Theobald Ziegler, of Strassburg, Germany.— "Sittliches Sein und sittliches Werden."— A short treatise of about 150 pages........ 1890

John Dewey, of the University of Chicago.— "Outlines of a Critical Theory of Ethics." — In the form of a text-book.................. 1891

Hans Gallwitz, Stadtpfarrer in Sigmaringen, Germany. — "Das Problem der Ethik in der Gegenwart."................................ 1891

S. Alexander, of Owens College, Manchester, England. — "Moral Order and Progress." 1891

Joseph Rickaby, S. J.— "Moral Philosophy." — Third Edition. — 1892

J. H. Muirhead, of Mason University College, Birmingham, England.— "The Elements of Ethics: An Introduction to Moral Philosophy." — In the form of a text-book................................ 1892

Borden P. Bowne, Boston University. — "The Principles of Morals." 1892

J. S. MacKenzie, of Cardiff, Wales.— "A Manual of Ethics." — In the form of a text-book.. 1892

Georg Simmel, of the University of Berlin. — "Einleitung in die Moralwissenschaft." — Two volumes....... 1892

Thomas H. Huxley, of England. — "Evolution and Ethics."— A collection of miscellaneous lectures...............................1893–1894

C. M. Williams. — "A Review of the Systems of Ethics Founded on the Theory of Evolution.".. 1893

James Seth, of University of Edinburg, Scotland. — "A Study of Ethical Principles."... 1894

E. Dühring, of Germany. — "Der Werth des Lebens." — Revised work.. 1894

Theodor Elsenhans, Stadtpfarrer in Reidlingen, a. D., Germany. — "Wesen und Entstehung des Gewissens. — Eine Psychologie der Ethik." 1894

Thomas Fowler and John Wilson, of Oxford, England. — "The Principles of Morals."... 1894

Charles F. D'Arcy, of Ireland. — "A Short Study of Ethics."......... 1895

James H. Hyslop, of Columbia College, New York City. — "The Elements of Ethics." — In the form of a text-book.................. 1895

Paul Rée, of Germany. — "Die Entstehung des Gewissens.".......... 1895

George Harris, of Andover Theological Seminary. — "Moral Evolution." — A collection of lectures................................ 1896

Walter L. Sheldon, Lecturer of the Ethical Society, of St. Louis. — "An Ethical Movement." — A collection of miscellaneous lectures 1896

B. Bosanquet, of London. — "Psychology of the Moral Self."........ 1897

James Mark Baldwin, of Princeton University. — "Social and Ethical Interpretations in Mental Development."........................ 1897

P. F. Fitzgerald, of England. — "The Rational or Scientific Ideal of Morality.".. 1897

Alexander Sutherland, of Australia. — "The Origin and Growth of the Moral Instinct." — Two volumes................................ 1898

W. R. Washington Sullivan, of the Ethical Religion Society of London. — "Morality as a Religion." — A collection of miscellaneous lectures 1898
Alexander Balmain Bruce, of the Free Church College, Glasgow, Scotland. — "The Moral Order of the World." — A collection of miscellaneous lectures 1899
A. Döring, of Berlin, Germany. — "Natürliche Sittenlehre." 1899
Alfred Fouillée, of France. — "Critique des Systems de Morale Contemporains." — Fourth edition 1899
Frank Thilly, of the University of Missouri. — "Introduction to Ethics." — In the form of a text-book 1900
George Herbert Palmer, of Harvard University. — "The Field of Ethics." 1901
Alfred Edward Taylor, of Owens College, Manchester, England. — "The Problem of Conduct: A Study in the Phenomenology of Ethics." 1901
Ernest Albee, of Cornell University. — "A History of English Utilitarianism." 1902
George Trumbull Ladd, of Yale University. — "Philosophy of Conduct." 1902

This of course is not a complete list, but it makes good working material for my purpose, and gives a bird's-eye view at one glance. It covers probably three-quarters of the whole literature, and practically all the leading works. The volumes are purposely arranged as far as possible in the chronological order of their first appearance, with the position of the writers, however, held at the present time or at the period of their death, so far as I am sure of these facts. It should perhaps also be stated that the works by Wundt, Paulsen, Gizycki and Guyan have been translated into English.

There should, however, be mentioned in addition, the "Ethical Library Series," edited by Prof. J. H. Muirhead, of England; the publications of the "Brooklyn Ethical Association;" the "Ethical Addresses Series," edited by S. Burns Weston of Philadelphia; a weekly "Ethics," published in London by Dr. Stanton Coit; the weekly "Ethische Kultur," edited by Dr. Foerster, of Zurich; the bimonthly "Ethical Record," edited by Percival Chubb, of New York; and the quarterly "International Journal of Ethics," edited by S. Burns Weston.

You will understand that this is a list only of those treatises dealing most *directly* with the problems of ethics. If I were to cover the whole field, the list of books would take up an entire volume instead of a few pages. Ethical theories of one type or another are hinted at, or more or less worked out in a large number of the treatises in philosophy or metaphysics, as for instance in "The World and the Individual," by Prof. Royce; Bradley's "Appearance and Reality;" Lotze's "Mikrokosmus;" or the classic "Geschichte des Materialismus," by Lange. Nearly all the more extended treatises on psychology are obliged to deal with it, and may have several chapters devoted to it, — especially as the writers here would perhaps regard it as also a sub-department of their larger science. Even the scholars dealing with the physical sciences may turn aside to have a word to say on ethics; and still more, the men dealing with biology. Now and then we have such a shocking piece of superficiality as the recent treatise on "World Riddles" by Ernst Haeckel. We can rest assured that he will have his say here on conscience and ethical ideals. But it is a work of which his brother biologists should be ashamed, for he went entirely outside of his province.

On the other hand there are very legitimate discussions of many of the problems of ethics in nearly all the leading treatises dealing with political science, anthropology or sociology. This is also true of many works in economics. The writers on the history of civilization are likewise obliged to deal with ethics.

Still more closely allied it is, of course, with the subjects of religion, theology, or biblical criticism. Any writers undertaking to give an extensive treatment of church doctrine must have their chapters on the ethics of the Bible, of Judaism, or of Christianity. As these, however, do not deal with the problem of ethics strictly as a science, I have not included them in my list.

Where, however, the connection is the closest would be in art and literature. A history of ethics in future times descriptive of the nineteenth century which should fail to consider the writings of George Eliot, Ibsen, Carlyle, Browning, Ruskin, and scores or hundreds of others, would be no real history of ethics at all. Such writers in the last thirty or forty years have exerted an enormous influence, both on ethical theories as well as ethical ideals. Poetry, the novel, the essay, the drama, must all be concerned with the ethical problem if they give us true works of art.

In my private library, for example, I have roughly divided my books into five sections: 1. History, Economics and the Social Sciences. 2. Philosophy, Psychology and Metaphysics. 3. The Natural Sciences. 4. Ethics, Religion, and Biblical Criticism. 5. Art and Literature. — And it may so happen that any morning when at work on some one ethical problem, I find myself turning to all five of these sections, and have books from every one of them lying before me on my table.

But if you will look over this list before you, certain interesting facts will be apparent at a glance. In the first place you will see at once how rapidly the treatises have been increasing in number during the last fifteen years. In the second place you will notice that the majority of the leading works come from the two great countries, England and Germany, although latterly America has been rapidly catching up, so far as number of books is concerned. Why it is that we do not have more literature on this subject from France I do not quite understand. It may be that many other treatises on ethics have appeared in that country; but if so one does not hear about them. My inference is that the work in this direction on the part of the scholars there, has been interwoven more particularly with their researches in psychology, anthropology, or the social sciences. But you will see that there is one treatise with a strikingly significant title from that country, as indicative of a bold tendency: "Esquisse d'une Morale sans Obligation ni Sanction," by M. Guyau. Janet and Fouillée have also done notable work in ethics in France. In the third place you will observe at once that the lead was taken by England. Glancing over the list we see four or five of the greatest works in ethics of modern times already issued in that country, such as "The Methods of Ethics," by Sidgwick; Spencer's "Principles of Ethics;" "The Science of Ethics," by Sir Leslie Stephen; "The

Prolegomena,'' by Green; and "The Types,'' by Martineau, before a single work of the rank of any one of these had appeared in Germany. Then, however, came the change when the mighty work, the "Ethik,'' by Wundt appeared in 1886, followed by an array of masterly treatises one after another during the last fifteen or sixteen years, such as the "System,'' by Paulsen; "Der Zweck im Recht,'' by Rudolph von Jhering; and a series of others. Germany has caught up and more. In this latter list should perhaps be included also the "Ethik,'' by the great Danish scholar, Höffding, of Copenhagen. Even from Italy we are now beginning to see mention of works with ethical titles, — although I cannot speak as to their contents.

In the fourth place you will notice the same tendency manifest as with the physical sciences, — the specializing in departments. The treatises covering the whole science of ethics as such, grow less in number. Looking carefully you will see the tendency increasing for scholars to take up subtopics and devote one or more books just to a single phase of the whole problem. There are two big volumes, "The Origin and Growth of the Moral Instinct,'' by Sutherand, devoted solely to elaborating the one aspect of the subject sketched in the chapter by Charles Darwin in "The Descent of Man;'' and a number of other works have this for their special field. It is already being asserted that within a short time there will be no science of ethics as such, but a list of special sciences into which the one larger field will be subdivided.

Some of these many works are school or college textbooks, prepared not as complete treatises, but in order to bring the facts before the younger students. One on my list is a "Moral Philosophy,'' strictly for Roman Catholics, by Joseph Rickaby, S. J., and a few of them are only single lectures, or very short treatises of perhaps a hundred pages touching on particular phases only.

And yet it is evident enough that a mass of literature of this kind could not have appeared in our age, and by such an array of thinkers, without certain marked results. The achievements may be regarded more as tendencies of thought than as accepted or well-defined principles. But even this would be a great deal. As I have asserted, many of these writers are thinkers of the first rank. Some of them have arisen through the natural sciences, and may have done first grade work there before they passed over to the department of ethics. Men like Wundt and Lotze began as students of medical science, and had a thorough foundation in that direction before they passed on to work along other lines. And in equipment I think that this would also apply to such workers as Sir Leslie Stephen and Herbert Spencer.

So far as the history of ethics is concerned, the work in this direction, to my mind, has as yet been rather unsatisfactory. It is a period when we should have expected the very best material of this nature. But the trouble has been from the specializing tendency. The man who could do this satisfactorily would need to be some one who was acquainted not only with the history of philosophy or of ethical theories, but had a wide grasp over the arts or literature for the last two thousand years or more. There is the little treatise, "History of Ethics," of 274 pages, by Sidgwick. Prof. Jodl, of Vienna, has written two volumes, "History of Ethics in Modern Times." The treatise, "Mental and Moral Science," by Alexander Bain, devotes three hundred pages to a history of ethical systems. Of the five hundred and seventy-seven compact pages in the work by Wundt about one hundred and forty are devoted to sketching "Die philosophischen Moralsysteme." Paulsen has about one hundred and fifty pages, but under a much more satisfactory title: "Umriss einer Geschichte der Lebensanschauung und Moralphilosophie."

Of course there is a great deal of material in all this, but on the whole it is rather disappointing in comparison with the rest of the work by such writers, with the possible exception of the chapters by Paulsen. The trouble with most of them is that they only give a history of ethical *theories* or *systems*. But of the ethical ideals in the great departments of art, literature and religion, we do not get enough. A history of ethics that does not include an examination of the three great tragedy writers of ancient Greece, — Aeschylus, Sophocles and Euripides, would strike me as painfully defective or inadequate. The work of Lecky, however, published in the '60's on "The History of European Morals" is a masterpiece of its kind for the one special period it covers. It is a profound misfortune that the other periods have not been worked out in the same way by other writers. It should be said, however, that there are some works in German by such men as Koestlin, Schmidt, Luthardt and Ziegler, which the writer has not been able to examine.

But, most of all, you will ask me, I assume, what in sum and substance is to be regarded as the new outcome of all this literature? What are the new tendencies? I should answer in the first place from the negative side, that an immense result has been accomplished by doing away with one mistaken theory which has been a stumbling block to ethical science or ethical philosophy for hundreds of years: — the theory which treated conscience as if it were a kind of an organ of the mind, just as the heart or the stomach may be an organ of the body. This belonged to the old psychology and held on most tenaciously from the religious side. Even where it was doubted, men did not have the right weapons with which to overthrow this illusion. It could not be done away with until the larger science of psychology also went through a transformation. The general doctrine of evolution did the work. One smiles now at thinking of an organ hidden away in the soul, pumping out ethical judgments somewhat in the same way as the heart pumps the blood through the body. But it may have been no smiling matter to deal with this theory fifty or one hundred years ago.

On the whole I should say that as a result of this whole doctrine of evolution, it is now pretty generally accepted by writers or students in ethical science that conscience is simply a phase of the functioning of the soul or of consciousness, and no more. In a word, we know now a little more definitely what our problem is; and this means a long step forward, I can assure you.

Along with this went the allied error that this same organ of the soul announced categorical judgments as to what was right and wrong on any or every life problem. The child was told: Look to your conscience, it is the voice of God. But now we no longer really have to argue this question at all. Another allied science has practically wiped that old theory out of existence; and that is the science of anthropology. It is this other science which has been laying the axe at the root of the tree and shaking the old foundations. The work has gone so far that I am bound to say one begins to tremble a little with anxiety as to what is to be the outcome. And the question is actually considered as to whether the soul as such *necessarily* functions in the form of conscience. The problem is now debated as to whether those feelings we think of as moral, are universal, — whether they have always existed in the human being. It is being asserted boldly that they are simply a transient phase in the evolution of consciousness.

On the positive side, another great result has been accomplished in the development of the historical side in the study of conscience. It is here where the fruits have been the greatest, and where, perhaps, the hardest work has been done. This, too, must be regarded as a contribution from the doctrine of evolution. If conscience is not an organ of the soul, but only a phase of the soul's functioning, then came the fascinating problem to work out the steps or processes according to which this functioning has displayed itself in the history of the human race. The absorbing problem, therefore, at the present time in ethical science is not so much the nature of conscience or the nature of the ethical ideal in itself; but the story of the development here, the chapters of growth in the ethical ideal or in the appearance of the moral sense we call conscience.

It has been established here now at last beyond dispute I should say, that growth or evolution applies in this direction just as much as it does in the bodily organism or in the animal kingdom. There is the same problem here as in biology. The question of origin, you understand, is something manifestly quite different from the question of growth or development. The first may take us into the realm of metaphysics. But the opportunity for co-ordinating the facts so as to set down in plain black and white the stages or steps through which the ethical sense has passed, or the ethical ideals have displayed themselves, is very great. It is in this direction probably where the best work will be done in the next few decades.

There is, however, as one can see, a change simply of interest or emphasis. In the old days with the ancient world, the interest lay rather in deciding what was the highest good, the *summum bonum*. But to-day owing to this doctrine of evolution, the interest lies rather, not in studying the ethical ideal of the highest good, but in tracing the genesis or development of those processes in consciousness which have led men to adopt certain ideals of the highest good, — in a word, the genesis and growth of conscience.

This much, therefore, I regard as an immense achievement evinced in the mass of literature from the time of Darwin: on the one hand, the realization of what the problem is, — the conception of conscience not as an organ, but as a phase of the functioning of the soul; and on the other hand, the disposition to study the science from the historic side.

It must be admitted frankly that the attitude of some of the scholars, even of the greatest, has been rather too bold or audacious. In a science where there is so much at stake, and where the personal element may so easily come in, where the problem is so subtle because of the subjective elements involved, surely there should be an excessive degree of caution and humility lest one venture too far in one's positive assertions. And I fear this humility and caution have not always been there. One sighs here for a little more of the manifestation of that modest hesitancy that was so apparent in the mind of Charles Darwin. It must be candidly confessed that some writers in ethics have dealt with the doctrine of evolution as a boy would do with his first jack-knife or hatchet: it has been employed as a weapon to smash things with, or with which to cut things to pieces. And some of our writers have slashed here and there with a defiant boldness that must make some of us a little ashamed. So, too, there has been the appallingly careless disposition to assume that in describing the processes of the development of conscience, the stages of its growth, one has also accounted for its origin; just as in the old days, perhaps, a careless thinker in chemistry may have felt that he had the whole explanation of a compound by describing the various elements that went into it, and by being able to put the compound together.

And yet, as a matter of fact, to-day we know no more as to the very first origin of the moral sense or of the functioning of the soul in this direction, than we know as to the origin of the living cell from inorganic matter. What is more, it is perfectly clear to my own mind that while, perhaps, the bridge may yet be covered between the organic and the inorganic, the bridge from the conscienceless to the conscience-possessing creature will never be constructed.

It has to be remembered that ethics is one of the very oldest of the sciences, where earnest searchers after truth have been working with persistence for upwards of twenty-five hundred years; and it behooves the new thinkers — for this reason, if for no other — to be cautious about their audacious statements and the revolutionizing tendencies from doctrines that are only a few decades old.

As regards this collection of books as a whole, some of you who are absorbed in the study of the physical sciences may ask in amazement what it is that is contained here. Many of these works are extensive treatises, heavy and weighty volumes by some of the leading thinkers or scholars of the world. How is it there is so much to say or dispute over, concerning the subject of conscience and the ethical ideal? What is it that these men are talking about and what are their problems? In answer to this I might suggest to you what queries a student in ethics would mentally put as he took up for the first time one of these treatises for perusal. In a general way he would desire at the outset to ascertain the author's attitude on perhaps five leading problems, about as follows:

(1) What is the writer's standpoint as to the theory of

the highest good or of the ethical ideal? Is he to be classed with one of the "schools," or has he a new position to defend? More especially, how does he stand with regard to English Utilitarianism? Every scholar must take his stand and declare himself in regard to this latter theory, inasmuch as it is the one most clear-cut, sharply defined, elaborately wrought out and most aggressive attitude of modern times. (2) What is the author's theory as to the nature of conscience? Is this something original or derived? In substance, what does he regard as the sanction for the moral ideal, or as the seat of authority impelling or commanding us to pursue this ideal? (3) What new contribution has the writer to make in the story of evolution or development of the ethical ideal and of conscience? If he regards this phase of soul-functioning as derived, then he is called upon to account for its origin, to unfold the elements out of which it is compounded, or because of which it has appeared. (4) What attitude does he take on the problem of the freedom of the will? The writer must make it clear once for all whether he is or is not a Determinist, with answers to the why or wherefore. He must pay his respects to this issue in one or several chapters, chiefly because it involves the problem of moral responsibility. (5) What view does he hold as to the relation between ethics and religion: to what extent or in what way is the God-problem involved? Nearly every writer will devote a part of his work to a consideration of this point.

These are the leading issues to be threshed out on the side of theory. But in all probability at least one-third of each of the treatises will be given over to the more practical aspects. The author will probably undertake to give a classification of the virtues or duties. Then he will be called upon to declare himself in the application of his special doctrines and to define his position on five main problems: (1) As to whether Society or the Individual ranks first in importance: which is the end in itself and to which one the other is subordinate. (2) As to the significance of Marriage and the Family. (3) As to Property and the Industrial problem: to what extent is he individualistic or socialistic. (4) As to the Church or Religious Institutions. (5) As to the function of the State in its relation to the other institutions and to the individual.

This second list of problems would constitute a separate department of Applied Ethics.

We can see therefore at a glance what an extensive field these writers may cover, and what a variety of topics they will be tempted to discuss. Before we are aware of it we shall be taken into the sciences of Economics, Religion, Politics, Law, History, Industrial Institutions and the vast Social Problem. Furthermore, if the author is not very cautious, before he is aware of it, he will have launched himself into the very heart of metaphysics.

It is also to be understood that a part of every treatise without exception must be made up of a consideration of other ethical theories, involving some history of ethical systems. In order to explain his own position, the writer must pass judgment on the schools which have existed from age to age. We can readily see therefore that as the world grows older the treatises on Ethics must grow larger and larger, — or else the science must be subdivided.

In a few words I shall endeavor to state the situation in regard to these various problems: although what I shall have to offer would scarcely be more than a syllabus or table of contents for a big volume.

I. As to the first issue — the ethical ideal or the highest good, — I should say that the drift of opinion now on the whole was *away* from the principle of "universal happiness" or English Utilitarianism. This must be said with excessive caution owing to the strength and eminence of the scholars who still represent this school. It was upheld by such master minds as John Stuart Mill, Alexander Bain, and Henry Sidgwick. So, too, Herbert Spencer has incorporated it into his great "System of Synthetic Philosophy." It is the standpoint of the eminent Danish scholar, Höffding, and of the German scholars, Carneri, Rudolph von Jhering and a number of others. We notice, however, among *some* of these men a very significant tendency to substitute another phrase

"The well-being of mankind," or "allgemeine Wohlfahrt," in place of happiness or "Glückseligkeit." Here we begin to see the influence of the doctrine of evolution.

This whole theory, however, has passed on to a distinctively new phase or type in the attitude of such men as Sir Leslie Stephen. According to this writer, we are dealing with what he terms graphically "social tissue." The immediate end is not happiness but the health of this social tissue. Pleasure of one kind or another is only the indirect aim or outcome. This standpoint should therefore go under a new name and be called Evolutional Utilitarianism; and in all probability it is in this form that the theory will continue to survive.

On the other hand, however, we notice a very distinct inclination on the part of many leading scholars to draw back from this whole standpoint, with the conviction that there is a certain other intellectual or spiritual element involved in the ethical ideal, apart from any feeling of pleasure or happiness. And in this direction we are meeting with a variety of standpoints which could not be classed under one name. In my own mind I think of the leaders in this other line as the Idealists; although it may not be quite fair to assume that there is not a distinctive element of idealism in some of the higher forms of Utilitarianism. For me it is much the deeper and the broader attitude, and is represented by some of the foremost thinkers, such as Wundt, Paulsen, Steinthal and a number of others in Germany, who emphatically repudiate the happiness principle.

Over in England this other tendency has taken form in a distinct school which is, however, represented by a most unsatisfactory phrase in the term "self-realization," as expressive of the true ethical ideal. The leader for this standpoint has been the late eminent scholar, Thomas Hill Green, whose "Prolegomena" is referred to by Mackenzie as "probably the most considerable contribution to ethical science that has been made in England during the nineteenth century." This group is often alluded to as constituting the *Perfectionist School*.

The easiest way in which to give a cue to the various standpoints from all sides, would be perhaps to mention some of the phrases used by the scholars in order to express the attitudes they assume concerning the ethical ideal. We have for example: "the attainment of a certain type of personality or bent of will," from James Seth; — "The greatest attainable well-being of mankind," from "The Principles of Morals," by Fowler and Wilson; — "conscious life in the full development of all its normal possibilities," from Borden P. Bowne; — "the preservation and perfection of human life," from Frank Thilly; — "The complete satisfaction of the ideal self," from George Trumbull Ladd; — "an equilibrium of conduct under the conditions of action," from S. Alexander; — "The realized will, the developed or satisfied self," from John Dewey; — "the peace of conscience secured by devoting one's self to the welfare of mankind," from Georg von Gizycki; — "The identity of perfection and of happiness," from Paul Janet; — "la vie à la fois la plus intense et la plus variée dans ses formes," from M. Guyau; — "the health of society," from Sir Leslie Stephen; — "the one subjective last end of all the human acts of a given individual, * * * that it may be well with him and his," from Joseph Rickaby, S. J.; — "the perfecting of man or the realization of the powers of the human soul," from Thomas Hill Green; — "the full exercise of the man's faculties in accordance with his proper individuality," from Charles F. D'Arcy; — "a desirable state of feeling called by whatever name — gratification, enjoyment, happiness," from Herbert Spencer; — "universal happiness from the desirable consciousness or feeling for the innumerable multitude of living beings present and to come," from Henry Sidgwick; — "Befriedigung der Bedürfnisse der menschlichen Natur nach ihrem ganzen Umfange," *i. e.*, "allgemeine Wohlfahrt," — from Höffding; — "self-realization, the objective consciousness of an attained end, which is accompanied by, but is not the same as, the feeling of pleasure," from W. R. Sorley; — "ein Sichbestimmen des Einzelnen nach der Idee der Gattung," from Strauss, the celebrated author of the "Leben Jesu;" — "the summum bonum is to realize the summus ego," from J. H. Muirhead; — "Wohl und Gedeihen der Gesellschaft," from Rudolph von Jhering; — "not happiness, but blessedness," from Carlyle; — "human welfare, Happiness, Being and Wellbeing combined; that is, Utility," from Alexander Bain; — "das Streben nach Glück, die Grundtriebfeder aller menschlichen Unternehmungen," from Carneri; — "die Verfolgung fremden Wohlseins als Zweck," from A. Döring; — "to make as complete a system as possible of the ideas and purposes of the self," from Bosanquet; — "Die Summe der Lust zu vermehren, deren die Welt sich erfreut," from Lotze; — "the natural good or perfection of man himself consists in the possession of abundant faculties, active and passive, fully developed, and in regular and equal exercise," from Edith Simcox; — "Alle seine Anlagen durch Übung zu Kräften und Fertigkeiten entfalten," from Paulsen.

So too, in a writer like Steinthal we come upon a reference to something which he calls: "Ein Reich des Intelligibeln," concerning which he says: "In diesem Reiche leben und weben, in ihm geniessen und schaffen, es fördern und mehren, ist der letzte Sinn der Sittlichkeit." In such a master mind and scientifically gifted man as Wundt, we even meet with a leaning towards mysticism in the effort to get away from the happiness principle, where he speaks about "ein allgemeiner Geist der Menschheit," as if it were something as real as one's own consciousness, and says: "Der Mensch kann das Gute nur erstreben, weil es ihn beglückt; aber das Gute selbst ist kein Glücksgut, sondern *ein objectives geistiges Erzeugniss.*"

On the other hand, perhaps the most striking of all at this moment is the attitude of two eminent writers who have come out emphatically with the assertion that there can be no one consistent expression for the highest good. As Carl Simmel, of Berlin, expresses it: "Die Annahme, dass der absolute Zweck nur einer sein könne, dass die Zwecke des wirklichen oder gesollten Handelns, sobald sie überhaupt zum Charakter des Endzwecks aufsteigen, nur in einem einzigen münden könnten — das ist einer der verbreitetsten Irrthümer des teleologischen Denkens." And the other writer, A. E. Taylor, of England, has recently published an extensive work, "The Problem of Conduct," apparently to establish the same point, according to the assertion: "All moral endeavor is bound to be a business of more or less unprincipled compromise," hence that ethics can have no foundation in metaphysics but only in empirical psychology.

II.–III. It is, however, in connection with the second and third classes of problems that the battle royal has been going on in ethical science since the time of Darwin, because it is here where the new historical method has played such an important role. What are the motives or sanctions for the ethical ideal? Is conscience something single and irreducible, an intuition, or is it derived, and is it a name for a complex series of feelings? It is here where, as some may think, the honor of the soul is at stake.

The influence in this direction has come supremely from the study of anthropology, — the customs and conditions of mind of primitive races, or of people living under a more primitive form of civilization. Then, too, the discovery of ancient literatures, the codes and documents of other races, has come like a revelation or an earthquake shock. If the moral sense is an original endowment, how are we to account for the contradictions we see in the way it announces itself?

At the same time, it should be remembered that the issue is not Intuitionalism versus Utilitarianism. The scholar who accepts the universal happiness principle as the ultimate aim, may nevertheless believe that there is an original injunction in the human soul commanding each and every one to work for this as an ideal. The great Lotze, for instance, assured us that the one supreme principle of all moral conduct must be found in the idea of benevolence. But it has very much upset others who accept this standpoint, when he asserts on the other hand: "Ein unaustilgbarer Keim des Guten ist dem menschlichen Geist im Gewissen angeboren, — unmittelbar in der Natur unseres Wesens begründet." Besides this there is the evolutional Intuitionalism of Herbert

Spencer, who teaches that the acquired experience of the human soul has become hereditary in certain ethical maxims or intuitions, just as it has in the axioms of mathematics. But this latter standpoint is tied up with the unsettled problem as to the possibility of the inheritance of acquired characteristics.

Yet in spite of the seeming contradictions in the codes or utterances of the moral sense, there are still a number of eminent scholars who believe that conscience is irreducible or underived, and therefore is an original endowment of the human soul. To quote from some of them: "There is a principle of self-development in man," in virtue of which, "he anticipates experience," Thomas Hill Green; "the feeling of the ought is primary, essential, unique; the judgments as to what one ought are the results of environment, education and reflection," George Trumbull Ladd; "A unique and irresoluble kind of knowledge,—" Martineau; "Reason discovering universal truth," Calderwood; "The consciousness of right and wrong is underived and witnesses to a supra-sensible principle in man," Pres. Schurman, of Cornell.

The standpoint here will depend a good deal on whether the writer accepts a certain spiritual element in the human being which is not in the animal consciousness, and therefore a certain intellectual element in conscience. The Idealists, as I have called them, will be inclined to defend an original element here. But those who regard the moral sense as having its basis only in feeling, may make a strong effort to reduce it to simpler elements. The favorite doctrine among this group of minds is that conscience is a feeling of self-approbation or self-disapprobation in connection with certain classes of conduct. We have, therefore, a long list of able scholars who have been working faithfully and persistently to trace the genesis of the moral sense simply as a feeling and to describe the steps of its evolution. The point with them is chiefly to account for the existence of Altruism, — how is it that instinctively we feel ashamed of selfishness?

The two big volumes by Sutherland are written for the purpose of tracing the genesis and growth of this sentiment from the earliest forms of the animal kingdom. With him it is simply to account for "methodized sympathy." The Association School, under the leadership of such a mind as Alexander Bain, may assume that they have explained it all in his statement: "Whenever an action is associated with disapprobation and punishment, there grows up in reference to it a state of mind indistinguishable from moral sentiment."

It is in such a treatise, however, as "Die Entstehung des Gewissens," by Paul Rée, that we have this derivative attitude worked out most completely. With him it is customs which develop moral feelings rather than moral feelings which develop customs. And the two heavy volumes by Jhering are written more than anything else to refute the position of Lotze, and to establish this main point: "Nicht die Natur, sondern die Geschichte ist die Urheberin des Sittlichen."

In sum and substance it means that the preservation of society required that some kind of a moral code should develop, and that this code should become fixed in the feelings; and therefore it came. It would not have developed if the individual had not required the existence of society for the sake of the preservation of his own existence.

This might be considered the attitude of such evolutionists as Guyau, Clifford, Carneri, Rée, Sutherland and others. In connection with this whole subject of the relation of conscience to evolution, the exciting moment came, however, when Huxley, the great biologist and disciple of Darwinism, gave his Romanes Lecture at Oxford on "Ethics and Evolution," and astonished nearly the whole world of scholars by his assertion that the ethical process and the cosmic process were opposed to each other, and that if we desire the development of the ethical process we must fight the cosmic process at every step of the way. It was the most important utterance, to my mind, in the science of ethics since the publication of "The Descent of Man," by Darwin. It was an assertion not that conscience had not been evolved, but that it had *not* come through the "struggle for existence," or by means of the same law according to which animal organisms had developed.

This meant calling a wholesome halt; the effect of that lecture has been tremendous, and may last for the whole of the twentieth century.

But, on the other hand, the group of Idealists may also insist that the whole discussion from this standpoint has not touched the real problem at all. It may give an explanation for the appearance of codes of morals like the Decalogue. But this is not conscience, they will say. It has not accounted for the impulse to realize an ideal in one's self, and of one's self. It has simply been explaining or describing the appearance of a certain codified altruism through the instinct of sympathy. In another direction, therefore, a novel and able effort has been made by Prof. Baldwin, of Princeton University, to account for the *subjective* element in conscience through the *imitative instinct*, as worked out in his treatise, "Social and Ethical Interpretations." How far he has succeeded, it is too soon for us to give an opinion.

It is very interesting, however, by the way, to note how some of these men judge as to whether the establishment of this theory concerning the derivative nature of conscience may affect its future influence, or its permanence as a factor in the human consciousness. And here the opinions differ widely. We have the frank confession of a man like Paul Rée, "Das Gewissen bleibt, gleich dem Held in der Fabel, nur so lange bei uns, als wir nicht fragen, woher es stammt; es verlässt uns, wenn wir diese Frage stellen. Grausamkeit und Mord sind nicht böse, sondern blos schädlich." Others will say that there will be no practical effect one way or the other.

In the case of the astute Sidgwick we have again the frank admission where he says, "A Utilitarian may reasonably desire on Utilitarian principles that some of his conclusions should be rejected by mankind generally; or even that the vulgar should keep aloof from his system as a whole, in so far as the inevitable indefiniteness and complexity of his calculations render it likely to lead to bad results in their hands." Again, we have the striking utterance from Guyau: "Quelque origine qu'on attribue à l'impulsion du devoir, si cette impulsion n'est pas justifiée par la raison, elle pourra se trouver gravement modifiée par le développment continu de la raison chez l'homme. * * * *Tout instinct tend à se détruire en devenant conscient.*"

But at any rate, as an outcome of the splendid work which has been going on for thirty years in connection with these two special problems — the nature and the evolution of conscience — we are in a much better position to go ahead and discuss the real issues. The historical foundation has now been laid. We know at last what we are dealing with — the facts as such are before us to grapple with in a way that they were not before the students in ethical science before the days of Darwin.

IV. When it comes to the problem of the freedom of the will, the atmosphere, it must be admitted, grows misty. In spite of everything we may do we shall find ourselves here within the domain of metaphysics. It is in connection with this issue that the various writers must declare themselves as to their general theory concerning the nature of soul or consciousness. They must take their stand for or against the appearance of a new element in the human creature in contrast with the animal kingdom.

The questions ordinarily put with regard to any of these writers would be: Is he a "Determinist" or an "Indeterminist," and does he regard the soul as merely a functioning of the body or as having a certain independent existence of its own? We can see, therefore, that in this department the writer is pretty sure to define his general position as to the nature of consciousness or the "soul," and to let us know to what extent he is or is not a "materialist," in ignoring or accepting a "spiritual" nature in man.

It may be said, I assume, that the drift of opinion among the scholars in ethics is now in favor of "Determinism," or against the old "freedom" standpoint. There is seemingly a shrinking reluctance at this point lest they admit themselves as unscientific. And it must be owned that a man who upholds the freedom of the will, will have to face a certain degree of contempt on the part of the physicist or the biologist, if not even the conventional psychologist. In this respect, therefore, — or perhaps not "therefore," — the writers in ethics have striven to be "up to date," and to feel themselves at one with the rest of the scientific world. We see, for instance, how one of these scholars announces it as the very starting-point or basis of his whole problem: "Ist, und in wie ferne ist bei einem consequent durchgeführten Determinismus, eine ethische Weltanschauung möglich?" — Carneri.

But language here must be taken with excessive caution. In reality there is not one but rather a number of problems involved. In the first instance, the issue may have to do purely with what we might term subjective experience and to what extent a freedom of the will exists strictly within the consciousness itself. It is the old mooted battle ground: must the will follow the strongest motive; does causality reign here as it does in the outer world? Again, on the other hand, the problem may rather apply to the issue whether the soul or consciousness is one of the determining factors in the whole of experience — objective and subjective alike, — or whether it simply accompanies the events of objective experience somewhat as if it were a function of the objective world.

Now a scholar may be a "Determinist" on one of these problems and an "Indeterminist" on the other, or he may be "Indeterminist" or "Determinist" on both of them.

On the whole one might say that in former days the discussion centered more on the subjective side; as to whether the will had to obey the strongest motive. All this went with the old-fashioned Faculty-Psychology. But the exciting aspect of the problem since the coming in of the new physics and the doctrine of the conservation of energy, has been rather as to whether the soul itself exerts any actual influence on the "outer world," as it is called; and is to be considered as a factor in the whole realm of causation. We are in the most intricate problem as to the relation between body and soul, or as to whether there is a distinction between soul and body at all.

The teacher in ethics is very much concerned with this whole problem because it is closely interwoven with the discussions of merit and demerit and the basis for moral responsibility. While the drift of opinion, as I have said, has been in favor of Determinism, it should, however, be stated that a few scholars during the last thirty years have held on most tenaciously to a belief in the freedom of the will *in the fullest sense of the term*, and some of these have been not of the second but of the first rank. It was upheld explicitly by Martineau, of England, and it was defended at least as a possibility by the great Lotze, of Germany, as we may see in a short chapter in his "Outlines of Practical Philosophy."

Others may contend that the law of causation holds strictly within the human consciousness, and use the phrase, "causation of character," while they may emphatically repudiate the notion that our spiritual experience is simply an effect or a functioning of physical forces. This latter view is explicit in the attitude of Thomas Hill Green. We see it in the very title of his opening chapter — "The Spiritual Principle in Knowledge and in Nature." To the question he himself propounds, "can the knowledge of nature be itself a part or product of nature?" — he gives an emphatic No.

Others still may contend that while the law of causation holds in both spheres, as it were, yet it is a different kind of causation *in the mind* from what we are dealing with in physical nature. This would be the attitude of Wundt. Hence it is, he claims, that while, in physical nature, any future event might be calculable — if one had a mind big enough to take in all the factors,— such a calculation would not be possible in the future acts of an individual *person*.

Still more, others may lose themselves completely in the realm of metaphysics and advocate a causation in *time*, but a freedom of the will *outside of time*.

It must be admitted that this is the dreariest and most exasperating department in all ethical science, and the one where the thoughtful reader will feel himself most baffled. Each new scholar, as he unfolds his system, will wish to take up this problem and work it out all over again. He is never satisfied with any other man's statement of it. He may wish to point out how he is "Determinist" in one aspect of the question and "Indeterminist" in another aspect of it. He will be anxious to qualify himself in a multitude of ways with the hope that he can throw some new light on this dark realm of metaphysical speculation. At times we may lay down one of these treatises with the feeling as if the writer had upheld both standpoints and — "you take your choice."

The fact of it is that the very terms "freedom of the will," "determinism," and "indeterminism" should be dropped from the vocabulary of ethics. If this could be done, one or more chapters might easily be dispensed with in many of these treatises. They are terms which arose in connection with a special period in the history of ethical theory, and are painfully interwoven with the other great department of theology. The retention of old terms which have become like worn coins, is sometimes a positive affliction to the advance of clear thinking. The old Greek was a happy man to have lived before the words "freedom of the will," and "determinism" had been coined or introduced into philosophy.

On the whole, perhaps the finest analysis of the problem is to be found in the treatises on ethics by Wundt and Green. But in passing I may give you a certain interesting compromise solution from Paulsen: "Freiheit des Menschen ist Herrschaft der Vernunft, Knechtschaft des Menschen ist Herrschaft der animalischen Begierden."

At the same time it must be taken into consideration that in such a condensed statement, little of what I have been saying on this special problem can have definite significance apart from the chapters where the problem is discussed. Had doctrinal theology never got mixed in here, it may be that this would never have been a department for the treatises on ethical science.

V. It will also be evident enough that when it comes to the subject of the relation between ethics and religion, we shall enter a domain of sentiment or feeling where we shall not have very clear sailing. But in this direction there has been one tremendous step taken in advance, and on this I wish to lay great emphasis. All the leading writers will have their opinions on this phase of the subject. They will take their stand as to the relation between the God-conception and conscience, and undertake to define themselves as to what extent at this point there is dependence or independence.

But the fact I wish to call your attention to is this : So far as I am aware, among this whole array of eminent scholars whose works I have listed before you, I doubt if there are more than four or five exceptions to my statement: that in case they found their conclusions seemingly in conflict with some part of the Bible, they would not still calmly hold on to their conclusions all the same. It would be done perhaps in reverence, but it would be done nevertheless. The exceptions, if any, would be men who took up the problem as clergymen and not as men of science. Ethics is no longer treated as a department of biblical criticism or of doctrinal theology. We shall appreciate how much this signifies when we recall the fact that the existence of conscience was long used as one of the natural "evidences" for the existence of God. To analyze it meant digging at the roots of theism. But ethical science has now practically won its freedom from the conventional authority of doctrinal religion or the church. In substance it implies that the scholar in ethics now feels that, like yourselves, he has a *body of facts* to deal with and interpret, that he has to handle his subject as a science and to accept whatever conclusions may come from his study.

If the great movement of evolution had accomplished nothing more than this in the department of ethics in the last forty years, it would have done a stupendous piece of work.

When, however, it comes to the subtle problem as to the relation between ethics and religion as such, it would perhaps surprise you to know how many of the scholars who are entirely free from the authority of any conventional theology, still recognize a close tie between the God-conception and conscience. They may qualify it by speaking of it as a "cosmic" relationship instead of a God-relationship, but the point is the same. On the practical side, it is the question: could the conscience still continue to exert its influence without the God-belief; while on the side of theory it is simply a question: is there a certain natural linkage or relation of dependence here, and if so, of what kind?

Almost every conceivable attitude of mind on this phase of the whole problem is represented by one or more of the modern scholars in ethical science. We have the negative view in the denial of any relationship here, — as illustrated in the old-fashioned, aggressive atheism and materialism still advocated by A. Dühring, of Germany, who is a most prolific writer, but not of course of the first rank. In his "Werth des Lebens," we come upon an emphatic denial of the very possibility of soul, immortality, or God, with an effort to found an ethics exclusively on sympathy and human affections. Then, too, there is the "atom-soul" and the naïve ethical monism of Haeckel, which is, however, only a sugar-coated, sentimental atheism and materialism. In the French scholar, Guyau, we likewise have a denial of duty, immortality and God, with a scheme for founding a morality *sans obligation ni sanction.* There was the brilliant mathematician, Clifford, giving a lecture on "Cosmic Emotion," or writing essays on "Ethics and Religion," and substituting a "Father-Man" in place of a "Father-God." We have the rather mournful negative agnosticism of an Edith Simcox, who yet would offer us a high subjective ethical Idealism quite independent of any God-belief. There is the "kosmisches Lebensgefühl" of Höffding. According to Janet, religion adds completeness to the moral life without being absolutely essential to it. Then there is the ethical, impersonal theism of Matthew Arnold with his definition of religion as, "morality touched with emotion," and his description of the God-conception as "The Eternal, not ourselves, that makes for righteousness."

For a scholar like Robert Flint, in his lectures on "Theism," conscience is a "delegated authority." — "Whose is this perfect authoritative supreme will to which all consciences point back? Whose, if not God's?" And for a

Cardinal Newman, "Conscience not only teaches that God is, but what he is," as he says in his "Grammar of Assent."

To some, the God-belief would be regarded as a kind of efflorescence of the moral sense. To others, like D'Arcy, conscience practically has no meaning unless linked with a belief in God. And likewise the statement of Ladd, of Yale: "The practical insufficiency of morality to sustain and elevate its own principles without support and help from religion, can be shown by an appeal to almost all the human experience which illustrates this subject." We have, however, in the other direction, the emphatic declaration of Green: "It is the very essence of moral duty to be imposed by man on himself." Hence we see that a man's opinion as to the actual linkage here, in the problem as to whether the moral law comes directly out of one's self or from God, does not necessarily depend on whether he is or is not a theist. On the other hand, a scholar like Wundt may turn the problem around by giving a broader definition to religion, as we see from his words: "Religion preaches to every mind that truth beyond which science can never go, namely, that the individual lives not for himself alone, but that his individual existence belongs to a universal psychical commonwealth, that his finite ends serve infinite ends whose ultimate fullfillment is hidden from his eyes." And in this sense he will find no difficulty as a man of science in recognizing an intimate relation between ethics and religion. In a writer like Royce, of Harvard, there is a disposition fairly to revel in the language of an exalted theism, and to fuse the religious and the ethical elements in a most striking way; while, however, the God-conception here becomes so vague as to convey scarcely more than a feeling or sentiment, to any one incapable of mastering the subtle abstractions of metaphysics.

On the whole we see an extreme reluctance on the part of most of these scholars to confess themselves as dealing with anything "transcendental," and yet with a preponderance of opinion that a cosmic relationship is linked with ethical motives. We see the term "ethical religion" gradually coming in, and it is a title of one of the books in the list which I have given you, by Mr. Salter, of Chicago.

It is apparent that the answers on the part of the various scholars to this fifth problem will be very much determined by personal temperament. The element of feeling is bound to come in at such a point. If a man himself has no "cosmic emotion," he will probably leave it out of his ethical system. If, on the other hand, he has a personal *feeling* of some connection between himself and the cosmos or the Law-maker of the cosmos, he will introduce it as a part of his theory.

About the most recent contribution to this whole problem comes from Prof. Palmer, of Harvard, in his little volume of Lectures, "The Field of Ethics," where he points out a certain antithesis between the provinces of ethics and religion, showing how the first points "man-ward" and the second, "God-ward;" and therefore how it is that the absorption of a person's interest in the one direction may temporarily weaken his interest in the other. And yet according to his opinion, "morality fulfills itself in religion, even though its gaze is directed man-ward rather than God-ward."

Taking it altogether it might be said that there is a consensus of opinion to the effect that the God-belief has not of itself called conscience into existence, nor conscience the God-belief; that neither one evolved out of the other, but that the two beliefs have been very closely interwoven historically and have exerted immense influence on each other. There is also a consensus of opinion, I should say, that the God-beliefs have historically served a great purpose in giving a fixity to ethical codes by impressing them more firmly on the human consciousness in the process of social development or social evolution, and also given a greater definiteness to the sense of moral obligation.

Of like interest would be the discussions as to the extent to which conscience and the ethical ideal may depend on the belief in the immortality of the soul. Here, too, in recent years the opinions are likewise diverse in the extreme. For a writer like Joseph Rickaby, of the Society of Jesus, it is to be expected that this belief is absolutely essential to his theory of conscience. On the other hand, we have the opposite standpoint of Gizycki who says, "The giving up of the belief in another world tends to lift a man's character. It is better to find one's blessedness through action than through adoration." But on the whole, looking through these various treatises where this phase of the subject is dealt with, it is quite plainly manifest that a faith in an ethical ideal may be very strong indeed even where the author is quite agnostic on all three problems as to "Gott, Freiheit und Unsterblichkeit."

It will naturally seem a little strange that in this short statement of mine, I have reserved such a brief space for reference to that great department of ethical science to which the leading writers would perhaps devote one-third of their treatises, or to the consideration of which many independent volumes have been given. It has to do, of course, with the problem of the application of the theories, —the department of applied ethics.

Each writer is called upon to tell how his theory helps to solve practical problems. But we can see at once that he has a task of enormous dimensions before him. The whole history of the human race is involved here; so too, a knowledge of the complex mechanism of the human consciousness, and also an acquaintance with a vast realm of practical affairs in the intricate movement or workings of the social forces. It is therefore to be expected that in this direction the first results must be crude and unsatisfactory. It is just where we are the most deeply and personally concerned, and where we should be most anxious to have light; but where the light will come the most slowly.

What is more, in this part of the subject we are dealing not with a fixed form of the ethical ideal, but with such an ideal in the process of the making. If there is one fact which has been established by the scholars in this last epoch since the time of Darwin, it is just this: that the ethical ideal on its practical side is a progressive one, and must assume new forms from age to age. It is the fundamental thought of Alexander's "Moral Order and Progress," who tells us there: "Every moral ideal is an arrested moment in the passage from one ideal to a higher."

We can also feel assured that in this great department of ethics the social environment or atmosphere in which the scholar or student has lived or been educated, must exert an enormous influence upon him in spite of any effort he may make to the contrary. The German, the Englishman, the Frenchman or the American cannot possibly be expected to handle these issues in the same way. When it comes to such questions as: the relation of the State to the rights of the individual; does man exist for the State or the State for man and which one is the end in itself; the meaning of "Justice;" the function of the Family, and the normal position and sphere of woman; the rights of society over children as contrasted with the rights of the parent; the permanence or dissolubility of the Marriage tie; the ethical influence of the Trades Union; the right of private property, and to what extent this right is relative or absolute; the function of the Church, with its relation to the individual and to society, or the State; the extent to which law or government should undertake to control private conduct in the interest of the individual or of society; the responsibility of society for the individual, or of the individual to society; the true principles for the punishment of crime; the ideal form of life for the individual person and in what way he is to strive after perfection; the degree to which self-denial or the opposite, self-assertion, is the foundation principle of the moral ideal; — when it comes to answers for a variety of problems like these, it would be absurd to expect at this stage a unanimity of opinion. The very same theories or abstract principles will perhaps be found to lead, in different minds, to the most opposite conclusions when it comes to the application of the doctrines. There is also the whole department pertaining to the ethical instruction of the young in connection with the science of pedagogy, which I have left untouched.

Most interesting to me on the whole are the theories with regard to the personal ideal or what constitutes the perfect man. It would be interesting to stop for a moment and contrast the theories of George Eliot in her gospel of renunciation as worked out in "Romola," or the attitude of "non-resistance of evil" as urged by Tolstoi, with the "Over-Man" of such a writer as Nietzsche, — because in the latter we have the gauntlet thrown down to thousands of years of ethical experience or tradition.

Of almost equal interest would be the debates concerning the relationship between the individual and society; whether society exists for man or man for society. We may have a standpoint amounting to anarchistic individualism on the part of Herbert Spencer, or we may have whole treatises such as the two volumes by Jhering, written practically to establish the point that society is sovereign, that it makes the law, and that it is for the individual to fit in here as the spoke fits into the wheel.

The final outcome of all this discussion on the practical side will be of tremendous value for mankind, but the real good of it you and I will not live to see.

In this whole statement, I have endeavored for the most part, to keep my personal convictions in the background, and I offer only one in conculsion, and it may be in the form of a prophecy. I cannot help thinking that ere long a reaction is to set in. The doctrine of evolution has been pushed too far, or tried as a key to solve too many problems. In its later form it was so new and striking that we had to expect that it would be employed in every possible way. The scholar in ethics has been inclined to run wild with it, as perhaps also the student in the physical sciences, — although on this latter point I should not venture to speak.

For a time it has seemed to unsettle every point in ethical science. There has been too much biology mixed in with the discussions in this department of research. I look for a still greater reaction in favor of the school of Idealists. It is my opinion that more rather than less will be made of conscience among the next generation of scholars, and that the subjective side is to assert its rights to more recognition.

But in this you are at once conscious that I am confessing myself in favor of those Idealists, and showing my personal bias. In spite of the array of scholars against me and in spite of the tendency of the age, — with all due respect and reverence for the minds of the men of science before me, with the consciousness that one must be modest in saying it, and that it should be said softly and in a whisper — nevertheless, gentlemen, *I still believe in the freedom of the will.*

A FURTHER LIST OF SHORT PASSAGES FROM VARIOUS WRITERS ILLUSTRATING THE DIVERSE STANDPOINTS ON SOME OF THE PROBLEMS MENTIONED IN THE PRECEDING PAPER.

I. Concerning Ethics as a Science.

"In the case of the physical sciences, at least, we can obtain knowledge which, within its own sphere, is entirely independent of the metaphysician's theories. Is not this true in all cases, and therefore in those cases in which the science is concerned with the conduct and character of human beings? May we not discover propositions about the relations of men to each other and the internal relations of the individual human being, which will be equally independent of metaphysical disputes? As we assign the relations between parts of space without asking what is space in itself, may we not determine rules about men without asking what is meant, for example, by personal unity, or what is the true mode of distinguishing object from subject? * * * The problem is, in fact, to discover the scientific form of morality, or, in other words, to discover what is the general characteristic, so far as science can grasp it, of the moral sentiments." — "The Science of Ethics," by Leslie Stephen.

"If we may treat facts of human feeling, and imagination, and judgment by scientific method, may sift them, classify them, concatenate and explain them, interpret their import and reason speculatively about their implicates, it is difficult to see why we may not properly speak of a possible 'science of ethics.'" "Ethics results from the scientific study of human conduct — its sources, its development, its sanctions, and its most general principles." — "Philosophy of Conduct," by George Trumbull Ladd.

"Es sind zwei Aufgaben der wissenschaftlichen Ethik zu unterscheiden. Dieselbe ist teils eine historische, teils eine philosophische Wissenschaft. Die historische oder vergleichende Ethik sucht die positive Moralität so darzustellen, wie sie zu einer gegebenen Zeit bei einem gegebenen Volke auftritt, sucht nachzuweisen, welche Entwickelung sie unter verschiedenen Verhältnissen erleidet, und die verschiedenen Formen zu vergleichen, die sie zu verschiedenen Zeiten bei verschiedenen Völkern annehmen kann. Sie sucht die Ursachen dieser verschiedenen Entwickelungsstufen und Formen in bestimmten physischen, psychologischen und historischen Verhältnissen aufzufinden. Die philosophische Ethik hat zur Aufgabe nicht die Beschreibung und Erklärung gegebener ethischer Erscheinungen, sondern deren Wertschätzung. Sie ist eine praktische Wissenschaft und setzt voraus, dass wir uns Zwecke gestellt haben, die durch menschliche Handlungen verwirklicht werden sollen." — "Ethik," by Harald Höffding.

"In der Bearbeitung wissenschaftlicher Aufgaben sind seit langer Zeit zwei von einander abweichende Standpunkte der Betrachtung zur Geltung gekommen: der explicative und der normative. Jener hat die Gegenstände in Bezug auf ihr thatsächliches Verhalten im Auge, dass er durch die Verknüpfung des innerlich Verwandten oder des nach äusseren Merkmalen Zusammengehörigen dem Verständnisse näher zu bringen sucht. Dieser betracht et die Objecte mit Rücksicht auf bestimmte Regeln, die an ihnen zum Ausdruck gelangen, und die er zugleich als Forderungen jedem einzelnen Objecte gegenüber zur Anwendung bringt. Dort gelten daher alle Thatsachen an sich als gleichwerthige; hier werden sie geflissentlich einer Werthschätzung unterworfen, indem man entweder von dem abstrahirt, was den aufgestellten Regeln widerstreitet, oder letzteres ausdrücklich als ein normwidriges dem normalen, die Regel bestätigenden Verhalten entgegenstellt. * * * So ist das Sittliche die letzte Quelle des Normbegriffs, und die Ethik ist die ursprüngliche Normwissenschaft."— "Ethik," by Wilhelm Wundt.

"The problem is not, what are the facts or phenomena of morality? but, How are we to interpret the facts? What is their ultimate significance?" — "A Study of Ethical Principles," by James Seth.

"Ethics is the Science of the Art of Life. It is concerned with the principles which underlie the estimation of conduct." — "A Short Study of Ethics," by Charles F. D'Arcy.

"Ethics is an empirical science having its basis in the wider science of psychology. Its primary object is to effect an analysis of the moral sentiments, *i. e.*, certain peculiar forms of emotion which are commonly aroused in us when we contemplate the past or prospective actions both of other persons and of ourselves." — "The Problem of Conduct," by Alfred Edward Taylor.

"Die Ethik hat nur, was ihr dargeboten wird, und kann nichts weiteres — woher auch? — hinzubringen. Sie findet den Menschen, wie er ist, forscht nach, wieso er zu dem, was er ist, geworden sein mag, und bildet sich ein Urtheil über das, was der Mensch sein kann. Was der Mensch sein sollte oder könnte, ist eine Frage, die für die moderne Ethik gar keinen Sinn mehr hat." — "Grundlegung der Ethik," by Carneri.

"Die Moralgesetze sind Naturgesetze und werden erkannt wie Naturgesetze, in demselben Sinn, in welchem die Vorschriften der Diätetik Naturgesetze sind und als solche erkannt werden. Es sind Regeln, auf deren Innehaltung die menschliche Wohlfahrt beruht." — "System der Ethik," by Friedrich Paulsen.

"That we place a value upon things, that we call them right or good, wrong or bad, is the important fact in ethics, is what makes a science of ethics possible." — "Introduction to Ethics," by Frank Thilly.

"Practical Philosophy may be defined, at least provisionally, as the science of the causes which determine human action or conduct, and of the differences which distinguish one kind of action or one mode of conduct from another. Corresponding to this science, there will be an art, the art of regulating conduct, whether that conduct be our own or the conduct of others." — "The Principles of Morals," by Fowler and Wilson.

"The aim of ethics is to render scientific, *i. e.*, true, and as far as possible systematic — the apparent cognitions that most men have of the rightness or reasonableness of conduct, whether the conduct be considered as right in itself, or as the means to some end conceived as ultimately good." — "The Methods of Ethics," by Henry Sidgwick.

"Ethics deals with conduct in its entirety, with reference, that is, to what makes it conduct, its end, its real meaning. Ethics is the science of conduct, understanding by conduct man's activity in its whole reach." — "Outlines of a Critical Theory of Ethics," by John Dewey.

"Men are prone to criticise themselves and others, and cannot help admiring in various degrees some expressions of affection and will, and condemning others. These current judgments constitute a body of ethical facts; and it is the aim of ethical science to strip from them their accidental, impulsive, unreflecting character; to trace them to their ultimate seat in the constitution of our nature and our world; and to exhibit, not as a concrete picture, but in its universal essence, the ideal of individual and social perfection. To interpret, to vindicate, and systematize the moral sentiments, constitutes the business of this department of thought." — "Types of Ethical Theory," by James Martineau.

"Wir müssen die Idee mitten in die mechanische Denkweise hineinstellen, müssen in voller Anerkennung der mechanischen Welt dennoch den Idealismus unsrer Gesinnung betätigen. Wie dies geschehen könne? dies zu zeigen ist Aufgabe der Ethik." — "Allgemeine Ethik," by H. Steinthal.

"Unsere Aufgabe ist keine geringere, als in widerspruchloser Weise darzuthun, dass der Monismus zu einem Begriff der Sittlichkeit führt, welcher trotz dem Causalgesetz und dem unvermeidlich daraus erfolgenden Determinismus von hohem Werth ist." — "Grundlegung der Ethik," by Carneri.

II. — Theories with Regard to the Ethical Ideal or the Highest Good.

"The end must consist in some form of self-realization, *i. e.*, in some form of the development of character — the end, in short, ought to be described rather as perfection than as happiness. — "A Manual of Ethics," by John S. Mackenzie.

"This, as it seems to me, represents the real difference between the utilitarian and the evolutionist criterion. The one lays down as a criterion the happiness, the other the health of society. The two are not really divergent; on the contrary, they necessarily tend to coincide; but the latter satisfies the conditions of a scientific criterion in a sense in which the former fails." — "The Science of Ethics," by Leslie Stephen.

"All men do all things for happiness, though not all place their happiness in the same thing." — "Moral Philosophy, or Ethics and Natural Law," by Joseph Rickaby, S. J.

"As the watchword of Hedonism may be said to be Self-satisfaction or Self-gratification, and as that of Rigorism is apt to be Self-sacrifice or Self-denial, so the watchword of Eudaemonism may be said to be Self-realization or Self-fulfillment." — "A Study of Ethical Principles," by James Seth.

"The theory we want to maintain is one that would found a supposed duty, and a supposed possible effort, on the part of the individual to make himself better, upon an ideal in him of a possible moral perfection, upon a conception actuating him of something that he may possibly become as an absolute end in himself." — "Prolegomena to Ethics," by Thomas Hill Green.

"There is no escape from the admission that in calling good the conduct which subserves life, and bad the conduct which hinders or destroys it, and in so implying that life is a blessing and not a curse, we are inevitably asserting that conduct is good or bad according as its total effects are pleasurable or painful." — "The Data of Ethics," by Herbert Spencer.

"By Utilitarianism is here meant the ethical theory, first distinctly formulated by Bentham, that the conduct which, under any given circumstances, is externally or objectively right, is that which will produce the greatest amount of happiness on the whole; that is, taking into account all whose happiness is affected by the conduct. It would tend to clearness if we might call this principle, and the method based upon it, by some such name as 'Universalistic Hedonism,' and I have therefore sometimes ventured to use this term, in spite of its cumbrousness." — "The Methods of Ethics," by Henry Sidgwick.

"To show that happiness and virtuous conduct, are, for human beings in their historical evolution, largely interdependent, is quite a different thing from showing that the virtuousness of virtuous conduct consists solely in its utility to produce happiness." — "Philosophy of Conduct," by George Trumbull Ladd.

"Nous croyons qu'une morale exclusivement scientifique, pour être complète, doit admettre que la recherche du *plaisir* n'est que la conséquence même de l'effort instinctif pour maintenir et accroître la *vie:* le *but* qui, de fait, *détermine* toute action consciente est aussi la *cause* qui *produit* toute action inconsciente: c'est donc la vie même, la vie à la fois la plus intense et la plus variée dans ses formes. Depuis le premier tressaillement de l'embryon dans le sein maternel jusqu'à la dernière convulsion du vieillard, tout mouvement de l'être a eu pour *cause* la vie en son évolution; cette cause universelle de nos actes, à un autre point de vue, en est l'effet constant et la *fin*." — "Esquisse d'une Morale," by M. Guyau.

"Das objektive Prinzip, das Prinzip für die Feststellung des Inhalts der Ethik und für die Wertschätzung der menschlichen Handlungen wird hier also das Prinzip der allgemeinen Wohlfahrt. Diesem Prinzip zufolge ist keine Handlung und keine durch Handlung begründete Institution oder Lebensform von Wert, sofern sie nicht das Leben und das Glück bewusster Wesen befördert." — "Ethik," by Harald Höffding.

"Aus lauter Nullen lässt sich keine Grösse bilden. Wenn das individuelle Lustgefühl als solches sittlich werthlos ist, so ist es auch das Lustgefühl Vieler oder Aller. Der Utilitarismus ist daher nichts als ein erweiterter Egoismus. Eben desshalb aber, weil im Gebiet individueller Willensantriebe jene Ergänzung der endlichen Beschränktheit im wirklichen Leben niemals eintreten kann, ist dieselbe hier nicht in der Form subjectiver Glücksgefühle vorhanden, die als solche niemals einen allgemeinen Werth gewinnen können, sondern in Gestalt objectiver geistiger Werthe, welche aus dem gemeinsamen Geistesleben der Menschheit hervorgehen, um dann wieder auf das Einzelleben veredelnd zurückzuwirken, nicht damit sie sich hier in eine objectiv werthlose Summe von Einzelglück verlieren, sondern damit aus der schöpferischen Kraft individuellen Geisteslebens neue objective Werthe von noch reicherem Inhalte entstehen." — "Ethik," by Wilhelm Wundt.

"There is such a thing as moral judgment of conduct only upon the assumption that this conduct leads to pleasure or pain. But to this conscience joins the further truth, that it is not the effort after our own, but only that for the production of another's felicity, which is ethically meritorious; — and, accordingly, that the *idea of benevolence must give us the sole supreme principle of all moral conduct.*" — "Outlines of Practical Philosophy," by Lotze.

"The supreme moral law, the categorical imperative, receives therefore this form: *Seek peace of conscience in devoting thyself to the welfare of mankind.*" — "A Student's Manual of Ethical Philosophy," by G. von Gizycki.

"Durch die Sittlichkeit schafft sich der Mench um: aus einem Natur-Individuum macht er sich zur intelligiblen Person, zum Bürger eines intelligiblen Reiches." * * * "Es giebt über der Natur ein Reich des Intelligibeln. Alle Gebilde, Einrichtungen, des Wohlwollens und des Rechts, alle Erkenntnisse der Wissenschaft, alle Anschauungen der Kunst, alle Formen menschlichen Fleisses, alle Erfindungen zur Hebung menschlichen Daseins, welche das Menschengeschlecht im Laufe seines Lebens erzeugt hat, und erzeugen wird, bilden dieses Reich, dessen Element der selbstbewusste freie Geist ist."— "Allgemeine Ethik," by H. Steinthal.

"What will remain, after such an examination of the Self of common sense, will be the really deep and important persuasion that he ought to possess or to create for himself, despite this chaos, some one principle, some finally significant contrast, whereby he should be able, with an united and permanent meaning, to identify that portion of the world's life which is to be, in the larger sense, his own, and whereby he should become able to contrast with this. his larger Self, all the rest of the world of life." — "The World and the Individual," by Josiah Royce.

"The good life as a whole is a system of conscious acts, where each function has its limits prescribed to it by the demands of all other functions, so that no faculty shall perform its functions to the detriment of another." — "Moral Order and Progress," by S. Alexander.

"The end of Ethics is not the greatest happiness of the greatest number. Your happiness is of no use to the community, except in so far as it tends to make you a more efficient citizen — that is to say, happiness is not to be desired for its own sake, but for the sake of something else. If any end is pointed to, it is the end of increased efficiency in each man's special work, as well as in the social functions which are common to all. A man must strive to be a better citizen, a better workman, a better son, husband or father." — "Lectures and Essays," by William Kingdon Clifford.

"Der Wert liegt nun nicht mehr in der Lust als solcher, sondern in den Funktionen, an welche sie geknüpft ist." — "System der Ethik," by Friedrich Paulsen.

"Whatever one may do, unless one introduces into the philosophy of pleasure a foreign and superior element, one can never find a rule which will explain why certain pleasures should be preferred to others." — Theory of Morals," by Paul Janet.

"— The broad rule of duty, the pursuit of perfection conditioned by the general laws of the universe, of which human reason is the highest exponent."—"Natural Law," by Edith Simcox.

"As the social instincts both of man and the lower animals have no doubt been developed by nearly the same steps, it would be advisable, if found practicable, to use the same definition in both cases, and to take as the standard of morality, the general good or welfare of the community, rather than the general happiness." — "The Descent of Man," by Charles Darwin.

"The moral sense is unyielding in its demands for the actualization, even here as far as may be, of the ultimate Divinely-implanted Ideal of perfection of life and Being." — "The Rational or Scientific Ideal of Morality," by P. F. Fitzgerald.

"Der Utilitarismus will ja eben die Aufgabe, an welcher der Evolutionismus scheitert, wirklich erfüllen; er gibt mir einen Imperativ, nach welchem ich meine Handlungen beurteilen kann, und er will beweisen, dass ich auch wirklich danach verfahre, dass diejenigen Handlungen, die gut sind, auch eine Maximisation des Glücks bezwecken, und umgekehrt, die von mir böse genannten die Summe des Glücks zu vermindern geeignet sind." — "Ethisches Wissen und ethisches Handeln," by Paul Hensel.

"That is moral which produces the greatest amount of good, present and future, to sentient creatures, and that is usually 'immoral' which causes avoidable pain, present and future, to them." — "The Scientific Basis of Morality," by G. Gore.

"Um das Leben auszuhalten, muss man es mit Sorgen erfüllen, sonst wird das Leben selbst eine schwerere Sorge als alle Sorgen des Lebens zuzammengenommen. * * * Wer sich an's Leben ketten will, der muss es mit möglichst reichem Inhalt zu erfüllen suchen, d. h. sich recht vielseitige Sorgen bereiten; dann kommt er mit Hülfe der Sorgen des Lebens über die Sorge des Lebens hinweg. * * * Um das Leben auf die Dauer aushalten zu können, darf man also weder bloss geniessen wollen, — muss man vielmehr handeln und wirken, sorgen und leisten, schaffen und arbeiten, und alles dies für Andere. * * * Der Pessimismus, weit entfernt, die Sittlichkeit zu schädigen, vielmehr einen Grundpfeiler derselben bildet, dessen Nichtbeachtung bisher die Unzulänglichkeit der allermeisten ethischen Systeme verursacht hat." — "Phänomenologie des sittlichen Bewusstseins," by Eduard von Hartmann.

III. Concerning the Meaning of Conscience.

"The idea, when it comes, has no external origin, and admits of no definition except in terms of itself. The right to which obligation refers is simply a perceived good; and the affirmation of obligation is the act by which the mind imposes duty upon itself in the presence of such a good. The free spirit thus imposing duty upon itself gives us the only meaning and experience of moral obligation." — "The Principles of Ethics," by Borden P. Bowne.

"Conscience is a name for the consciousness of moral distinctions and of the obligation to respect them." — "The Elements of Ethics," by James H. Hyslop.

"— A law within the mind and consciousness of the creature, whereby it shall measure and regulate its own behavior. This is the natural law of conscience." — "Moral Philosophy, or Ethics and Natural Law," by Joseph Rickaby, S. J.

" Conscience is a mere general name used to designate a series of complex phenomena, and not a separate special faculty." — " Introduction to Ethics," by Frank Thilly.

" The moral law being, in brief, conformity to the conditions of social welfare, conscience is the name of the intrinsic motives to such conformity." — " The Science of Ethics," by Sir Leslie Stephen.

" Whatever may be the historical origin of human morality, let us, then, admit that in the actual consciousness of humanity, or, at least, in that of the noblest groups of humanity, there exists the idea of a general and universal form for our actions, of a law which claims control of the reason, and commands the will." — " Theory of Morals," by Paul Janet.

" Wenn nun der Gefühlszustand des einzelnen Augenblicks, als Wirkung der eignen Handlung des Individuums im Bewusstsein mit dem durch die Vorstellung der Lebenstotalität bestimmten Gefühlszustande zusammentrifft, so wird ein neues Gefühl entstehen, das durch das gegenseitige Verhältnis jener Gefühle bestimmt ist, ein Verhältnis, das entweder harmonisch oder disharmonisch sein kann. In diesem, durch das Verhalten des momentanen Zustands zu dem durch die Rücksicht auf die Lebenstotalität bestimmten Zustande erzeugten Gefühle besteht die Wertschätzung. Das Vermögen, solche Gefühle zu haben, ist das Gewissen." — " Ethik," by Harald Höffding.

" — Es zweierlei ist, was wir behaupten: die entwickelnde Kraft der Erfahrung einerseits, aber ebenso sehr das ursprüngliche Vorhandensein des Keimes, auf den sie wirkt. Man wird nie Erfolg haben, wenn man in eine leere Seele hinein das Bewusstsein des Sollens nur vermittelst der Eindrücke der Erfahrung bringen will." — " Mikrokosmus," by H. Lotze.

"That which, when we become capable of reflection, we term conscience, consists in pleasure in forms of action furthering the welfare of society — forms gradually moulded to habit with the development of social relations, — and in a corresponding pain at the realization of having failed of such action; the knowledge of the demand by society as a whole or by a part of society, of action in accord with the general welfare, and the sense of the justice of this demand, constituting the feeling of obligation and duty." — " A Review of the Systems of Ethics founded on the Theory of Evolution," by C. M. Williams.

" The feeling of moral approbation or disapprobation, when applied to our own actions and characters, thus assuming the form of self-approbation or self-disapprobation, constitutes the moral sanction, strictly so called. It is this sanction which, to men of pure and elevated character, is the most powerful guardian of morality, and, to all men, it remains as the ultimate guardian, when the other sanctions have become inoperative. — " The Principles of Morals, " by Fowler and Wilson.

"Conscience is the critical perception we have of the relative authority of our several principles of action. The sense of that authority is implicitly contained in the mere natural strife of these principles within us: when explicitly brought into view by reflective self-knowledge, it assumes a systematic character, and asserts its prerogative as the judicial regulator of life." — "Types of Ethical Theory," by James Martineau.

"The general truths involved in moral judgments do not appear to be generalized truths dependent for their validity on an induction of particulars, but self-evident truths, known independently of induction." — "Handbook of Moral Philosophy," by Henry Calderwood.

"Der psychologische Vorgang, dessen logischen Abschluss die Selbstbeurtheilung bildet, ist aber zunächst kein Urtheilsprocess, sondern er tritt, ehe er sich zu diesem entwickelt, in der Form gefühlsstarker Vorstellungen auf, an die namentlich unmittelbar Affecte der Billigung und Missbilligung geknüpft sind. Indem diese Affecte mit einander in Streit gerathen, können sie zugleich die Antriebe zu entgegengesetzten Acten der Selbstbeurtheilung in sich schliessen. Die Sprache nennt alle diese inneren Zustände, sofern nur ihr selbstbewusster Ausdruck zu einem Urtheil über die eigenen Motive und den eigenen Charakter des wollenden Subjectes wird, das Gewissen." — "Ethik," by Wilhelm Wundt.

"We need not shrink from asserting as the basis of morality an unconditional duty, which yet is not a duty to do anything unconditionally except to fulfill that unconditional duty." — "Prolegomena to Ethics," by Thomas Hill Green.

"Conscience is seen to be a cognitive or intellectual power, not a form of feeling, nor a combination of feelings. Feeling is not in itself of the nature of regulative truth." — "Handbook of Moral Philosophy," by Henry Calderwood.

"A moral being is one who is capable of comparing his past and future actions or motives, and of approving or disapproving of them. We have no reason to suppose that any of the lower animals have this capacity." — "The Descent of Man," by Charles Darwin.

"Das Gewissen ist in seinem Ursprung nichts anderes, als das Bewusstsein von der Sitte oder das Dasein der Sitte im Bewusstsein des Individuums, mit Einschluss jener Sanktionen durch Menschen und Götter." — "System der Ethik," by Friedrich Paulsen.

"Das Gewissen ist das unmittelbare Bewusstsein des für uns schlechthin verbindlichen göttlichen Willens, welches sich unwillkürlich geltend macht. Gesetzgebend und gebietend, richtend und strafend, vorangehend und nachfolgend, mahnend und warnend wird es genannt, je nachdem es vor order nach der That seine Rolle spielt. — "Das Gewissen," by Wilh. Schmidt.

"The only way in which we can really show the absoluteness of moral judgments is by basing them upon reason. Then sympathy is raised into the form of the judgment that an act is right or wrong, according as it does or does not tend to the realization of the ideal or spiritual nature. An act is not right because it is felt to be so, but we feel it to be so because it is right." — "Hedonistic Theories," by John Watson.

"Conscience is not, as some believe, a special faculty which is the source of obligation, and which, as its own distinct province, sits in judgment upon conduct, and pronounces the decisive 'ought' of approval, or 'ought not' of disapproval. Conscience is simply the consciousness of obligation." — "A Short Study of Ethics," by Charles F. D'Arcy.

IV. Theories Concerning the Origin and Growth of Conscience and the Ethical Ideal.

"It appears to me that, if we recognize man as a being having feelings towards others as well as towards himself, as sympathetic and resentful as well as self-regarding, with a reason capable of comparing the ends to which his feelings impel him and of finding means for the attainment of those ends, there is no difficulty, except in detail, in explaining the process by which men arrive either at the moral judgments in which they agree or at those in which they differ." — "The Principles of Morals," by Fowler and Wilson.

"It seems to be frequently assumed, that if it can be shown how certain mental phenomena, thoughts or feelings, have grown up — if we can point to the antecedent phenomena, of which they are the natural consequents — then suddenly the phenomena which we began by investigating have vanished; they are no longer there, but something else which we have mistaken for them: the 'elements' of which they are said to be 'composed.' The illegitimacy of this inference will, I think, be allowed as soon as it is clearly contemplated." — "The Methods of Ethics," by Henry Sidgwick.

"Any animal whatever, endowed with well-marked social instincts, the parental and filial affections being here included, would inevitably acquire a moral sense or conscience, as soon as its intellectual powers had become as well, or nearly as well developed, as in man." — "The Descent of Man," by Charles Darwin.

"The sense of duty assumes an appearance of inscrutable origin because it arises at aperiod of which we have no memory." * * * "As members of the community, we learn to judge others by a standard of duty; and then, if our natures are fine enough to permit of it, we learn to judge our own actions by the same standard. Self-respect is thus the inward application of an outwardly prevalent mode of thinking." — "The Origin and Growth of the Moral Instinct," by Alexander Sutherland.

"Suppose that a man has done something obviously harmful to the community. Either some immediate desire, or his individual self, has for once proved stronger than the tribal self. When the tribal self wakes up, the man says, 'In the name of the tribe, I do not like this thing that I, as an individual, have done.' This Self-judgment in the name of the tribe is called Conscience. If the man goes further and draws from this act and others an inference about his own character, he may say, 'In the name of the tribe, I do not like my individual self.' This is remorse. * * * The voice of conscience is the voice of our Father Man who is within us; the accumulated instinct of the race is poured into each one of us, and overflows us, as if the ocean were poured into a cup." — "Lectures and Essays," by William Kingdon Clifford.

"Die Strafe ist nicht eine Folge des Gerechtigkeitsgefühls, sondern das Gerechtigkeitsgefühl ist eine Folge der Strafe." — "Die Entstehung des Gewissens," by Paul Rée.

"That progressive modification of civilization which passes by the name of the 'evolution of society,' is, in fact, a process of an essentially different character, both from that which brings about the evolution of species in the state of nature, and from that which gives rise to the evolution of varieties, in the state of art. * * * Social progress means a checking of the cosmic process at every step and the substitution for it of another, which may be called the ethical process; the end of which is not the survival of those who happen to be the fittest, in respect of the whole of the conditions which obtain, but of those who are ethically the best." — "Evolution and Ethics," by Thomas H. Huxley.

"Evolution is not the foundation of morality, but the manifestation of the principle on which it depends. Morality cannot be explained by means of its own development, without reference to the self-consciousness which makes that development possible. However valuable may be the information we get from experience as to the gradual evolution of conduct, its nature and end can only be explained by a principle that transcends experience." — "Ethics of Naturalism," by W. R. Sorley.

"Mag das Gewissen entstanden sein, wie und wo man will; das ist eine Frage der Wissenschaft, durchaus nicht verschieden von der über das Verschwinden des Zwischenknochens beim Menschen; was mir zum Handeln not thut, das ist, dass das Gewissen nun in mir vorhanden ist, Gehorsam fordert und ich ihm zu gehorchen habe." — "Ethisches Wissen und ethisches Handeln," by Paul Hensel.

"Le noumène, au sens moral et non purement négatif, c'est nous qui le faisons; il n'acquiert de valeur morale qu'en vertu de type sur lequel nous nous le représentons : c'est une construction de notre esprit, de notre imagination métaphysique." * * * "Au fond, la sanction dite morale et réellement sensible est un cas particulier de cette loi naturelle selon laquelle tout déploiement de l'activité est accompagné de plaisir. Ce plaisir diminue, disparait et laisse place à la souffrance selon les résistances intérieures ou extérieures que l'activité rencontre." — "Esquisse d'une Morale," by M. Guyau.

"Wir sind berechtigt, ja genötigt, eine besondere Anlage für das Gewissen anzunehmen, weil die Eigenart der Gewissenserscheinung im Individuum und in der Geschichte und die Gleichheit ihrer Aüsserungen bei genügend vorhandenen Entwicklungsbedingungen der Ableitung aus anderen Factoren widerstrebt. Die Anlage selbst aber hat den Charakter eines Keimes, der wie im Reiche des Organischen auf gewisse Reize hin sich entwickelt, und sie gleicht den Instincten der Tiere in der Unmittelbarkeit, mit der sie als Motiv zu bestimmten Handlungen sich geltend macht. Dabei hebt sich aber doch die sittliche Anlage als eine rein geistige deutlich von anderen Anlagen des Menschen ab, auf welchen die körperliche Entwicklung beruht. Es bleibt also nichts anderes übrig, als die Gewissensanlage zu den angeborenen Elementen des höheren Geisteslebens zu rechnen, deren Verknüpfung mit bestimmten Orten oder Vorgängen im Nervensystem noch nicht gelungen ist." — "Wesen und Entstehung des Gewissens," by Theodor Elsenhans.

"Das Sittliche ist historisch nicht vom Individuum, sondern von der Gesellschaft aus gewonnen worden, und auch praktisch besteht das wahre Verhältniss desselben darin, dass die Gesellschaft dasselbe von ihm fordert." — "Der Zweck im Recht," by Rudolph von Jhering.

"The organism develops only by cultivating the habit of imitating; while the very value of imitation is that by it the organism acquires new accommodations by breaking up habits already acquired. The organism must be ready, by a habit of acting, to impair the habits of action it already has. And the origin of the moral sense by this method shows it to be an imitative function. We do right by habitually imitating a larger self whose injunctions run counter to the tendencies of our partial selves."— "Social and Ethical Interpretations in Mental Development," by James Mark Baldwin.

"Wie der Sabbat, so sind auch die Moralgesetze um des Menschen willen, nicht der Mensch um der Moralgesetze willen. Verlieren etwa die Regeln der Grammatik oder die Wortbedeutungen ihre Gültigkeit für den, der sich überzeugt, dass es auch bei ihrer Entstehung menschlich zugegangen sei? Nun, so wenig können die Sittengesetze auf diese Weise ihre Gültigkeit einbüssen." — "System der Ethik," by Friedrich Paulsen.

"Aus dem Begriff der Totalität wird sich uns ein Gesetz ergeben, auf Grund dessen alle Artenentwickelung vor sich geht, das Lebendige zum lebendigen Wesen, das lebendige Wesen zum denkenden Wesen, das denkende Wesen zum sittlichen Wesen sich erhebt. Wie das Denken hervorgeht aus dem Functioniren des menschlichen Organismus: so geht die Sittlichkeit aus dem Functioniren des Organismus hervor, den wir Staat nennen. Die ersten Spuren der Sittlichkeit, die wir an dem vorstaatlichen Zusammensein der Menschen voraussetzen können, verhalten sich zur vollentwickelten Sittlichkeit, wie das Denken das Thieres zum Denken des hochgebildeten Menschen." — "Grundlegung der Ethik," by Carneri.

"To make my position fully understood, it seems needful to add that, corresponding to the fundamental propositions of a developed Moral Science, there have been, and still are, developing in the race, certain fundamental intuitions; and that, though these moral intuitions are the results of accumulated experiences of Utility, gradually organized and inherited, they have come to be quite independent of conscious experience. Just in the same way that I believe the intuition of space, possessed by any living individual, to have arisen from organized and consolidated experiences of all antecedent individuals who bequeathed to him their slowly developed nervous organizations — just as I believe that this intuition, requiring only to be made definite and complete by personal experiences, has practically become a form of thought, apparently quite independent of experience; so do I believe that the experiences of utility organized and consolidated through all past generations of the human race, have been producing corresponding nervous modifications, which, by continued transmission and accumulation, have become in us certain faculties of moral intuition — certain emotions responding to right and wrong conduct, which have no apparent basis in the individual experiences of utility. I also hold that just as the space-intuition responds to the exact demonstrations of Geometry, and has its rough conclusions interpreted and verified by them; so will moral intuitions respond to the demonstrations of Moral Science, and will have their rough conclusions interpreted and verified by them." — "The Data of Ethics," by Herbert Spencer.

"I am very far from denying that the materials of the human constitution existed in lower orders. But in man the materials are differently compounded. As the combination of the same chemical elements at different potencies gives essentially different products, so the combination of the same materials gave different creatures. Inquiry concerning the origin of the sense of obligation is simply inquiry concerning the origin of man. Duty was not merely an advantage, a utility which man adopted after he had been man for a longer or shorter time. Without it man would not be man. It is his nature." — "Moral Evolution," by George Harris.

"Es bedarf dazu vielmehr der Mitwirkung einer seelischen Einheit, für welche die Vorstellung nur die Veranlassung ist, in einer bestimmten Weise, nämlich durch Erzeugung eines sittlichen Urteils, besser des sittlichen Gefühls, zu reagiren. Dass es aber gerade immer diese Form der Reaction ist, kann nur aus einer ursprünglichen Anlage der Seele erklärt werden. So wenig das Fallgesetz des Steins, der aus der Ruhelage in die Fallbewegung übergeht, eine von der nahen Erdmasse unabhängige Formel des Geschehens ausdrückt, so wenig können sich seelische Vorgänge nach Gesetzen aneinander knüpfen, die nicht durch eine entsprechende der Seele eigene Anlage bestimmt wären." — "Wesen und Entstehung des Gewissens," by Theodor Elsenhans.

"What we term immorality, sin, crime, wickedness, etc., may be scientifically regarded as moral pathology or functional mental disease in social subjects; and we may view moral diseases as being merely cerebral and analogous to ordinary bodily ones." — "The Scientific Basis of Morality," by G. Gore.

V. Theories Concerning the Freedom of the Will.

"Pull a body to the right with a force of twelve pounds, and to the left with a force of eight; it moves to the right. Imagine that body a mind aware of the forces which act upon it; it will move in the direction of that which, for whatever reason, appeals to it most; and in doing so, it will, just because it is conscious, act of itself, and will have the consciousness of freedom. A true explanation of this consciousness turns the flank of indeterminism." — "Moral Order and Progress," by S. Alexander."

"Starting from a multitude of elements absolutely at rest, no motion can be produced. Now how far soever we pursue a still further deduction, it nevertheless invariably presupposes other new motions; we are compelled to admit, that motion does not attain to actuality as the result of any cause whatever, but it is motion, without cause, and from the beginning. * * * And now if this must be once for all admitted as an existing fact, then there is no reason why perfectly new beginnings of a subsequent origin, that have no foundation in what is prior, should not also show themselves within the course of things; but after they have once taken their place in the coherent system of things actual, they bring after them those consequences which belong to them in their present combination with the rest of the world, according to general laws." — "Outlines of Practical Philosophy," by H. Lotze.

"Here we seem to be on the confines of human knowledge, and to be compelled to recognize that, in the sphere of human action as well as in that of metaphysical speculation, there are apparent contradictions which we cannot reconcile." — "The Principles of Morals," by Fowler and Wilson.

"Man, as an ethical being, is part of the universe, and as a part, he must be explained, not explained away. To interpret his moral life as mere 'appearance,' to depersonalize and thus to demoralize him, is to explain away his characteristic being. This pantheistic resolution of man into God is too rapid an explanation; the unity thus reached cannot be the true unity, since it negates, instead of explaining, the facts in question. Such an unethical unification might conceivably be a sufficient interpretation of Nature, and of man in so far as he is a natural being, and even in so far as he is an intellectual being; it is not a sufficient interpretation of man as man, or in his moral being. The reality of the moral life is bound up with the reality of human freedom, and the reality of freedom with the integrity of the moral personality. If I am a person, an 'Ego on my own account,' I am free; if I am not such a person or Ego, I am not free." — "A Study of Ethical Principles," by James Seth.

"Our conduct is the resultant of the attractions of external motives. In human conduct the dominating factor is the degree of affinity which exists between the internal nature and the external motives." — "The Origin and Growth of the Moral Instinct," by Alexander Sutherland.

"The moral life rests upon the presupposition that the law of cause and effect holds good just as much in the domain of human volition as in the material world — the law that no events take place without a cause, and none without effect." — "Ethical Philosophy," by G. von Gizycki.

"We evidently feel the solicitations which visit us to be mere phenomena, brought before a personality that is more than a phenomenon or than any string of phenomena — a free and judicial Ego, able to deal with the problem offered, and decide between the claimants that have entered our court." — "Types of Ethical Theory," by James Martineau.

"Our conclusion is that, while on the one hand his consciousness is throughout empirically conditioned, — in the sense that it would not be what at any time it is but for a series of events sensible or related to sensibility, some of them events in the past history of consciousness, others of them events affecting the animal system organic to consciousness, — on the other hand his consciousness would not be what it is, as knowing, or as a subject of intelligent experience, but for the self-realization or reproduction in it, through processes thus empirically conditioned, of an eternal consciousness, not existing in time but the condition of there being an order of time, not an object of experience but the condition of there being an intelligent experience, and in this sense not 'empirical' but 'intelligible.' In virtue of his character as knowing, therefore, we are entitled to say that man is, according to a certain well-defined meaning of the term, a 'free cause.' * * * To a will free in the sense of unmotived we can attach no meaning whatever. * * * It is strictly a contradiction to say that an action which a man's character determines, or which expresses his character, is one that he cannot help doing." — "Prolegomena to Ethics," by T. H. Green.

"Life would be intolerable if the will were not free to adapt itself, within moral limits, to the possible; but life would be impossible — would not be at all — if the will were free in some inconceivable manner to alter the nature of things by arbitrary ex post facto degrees." — "Natural Law," by Edith Simcox.

"I shall only add that, in any case, to reason about conduct is to assume that it is determinate. If actions be intrinsically arbitrary, or in so far as they are arbitrary, a theory of action must be a contradiction in terms. And thus, as it has been said, that whether we are or are not free, we must act as though we were free, I may say that whether conduct be or be not determinate, we must reason about it as though it were determinate." — "The Science of Ethics," by Leslie Stephen.

"Der Wellenschlag von Ursache und Wirkung, der in der Sinnenwelt in unendlicher Folge sich fortsetzt, bricht sich an jedem menschlichen Willen;

über ihn hat das Causalitätsgesetz keine Macht, sondern nur das Zweckgesetz. Der Wille ist der Natur gegenüber frei, er gehorcht nicht ihrem, sondern seinem eigenen Gesetz. Aber während sie keine Macht hat über ihn, hat er Macht über sie, sie muss ihm gehorchen, wenn er will — jeder menschliche Wille ist Quelle der Causalität für die äussere Welt. So lässt sich der Wille als das Ende und der Anfang der Causalitätsbewegung in der Natur bezeichnen — Wille heisst das Vermögen der eigenen Causalität gegenüber der Aussenwelt." — "Der Zweck im Recht," by Rudolph von Jhering.

"Wie wir also auch den Geist als Kraft frei nennen mögen, so bleibt er doch als Kraft immer durch mechanisches Gesetz determinirt, und ist, als Kraft angesehen, niemals in dem Sinne frei, als wäre er nicht vom Gesetz determinirt." — "Allgemeine Ethik," by H. Steinthal.

"—die Effecte der Willenshandlungen zwar stets durch bestimmte psychische Ursachen determinirt, *dass sie aber in diesen Ursachen selbst nicht schon enthalten sind.* * * * Eine unmittelbare Consequens dieses Verhältnisses ist es, dass auf geistigem Gebiet eine einigermassen zureichende Causalerklärung immer nur in rückläufiger Richtung, d. h. in Bezug auf die bereits abgelaufenen Causalreihen, nie aber in vorwärtsgehender Richtung möglich ist. Naturereignisse können wir unter günstigen Umständen mit Gewissheit voraussagen. Bei geistigen Ereignissen vermögen wir höchstens die allgemeine Richtung zu bestimmen, in der sie erfolgen, niemals aber die besondere Gestaltung, die sie annehmen werden. Es gibt eine geistige Geschichte der Vergangenheit, keine der Zukunft, und noch jeder geschichtsphilosophische Versuch, der sich vermass kommende Ereignisse vorauszusagen, ist auf bodenlose Abwege gerathen. Denn die Fiction der Laplaceschen Weltformel ist nicht bloss desshalb auf das geistige Geschehen unübertragbar, weil ihre Aufstellung hier an der unabsehbaren Complication der Ereignisse scheitert, sondern weil sie an und für sich mit den Gesetzen des geistigen Geschehens im Widerspruche steht." — "Ethik," by Wilhelm Wundt.

"The entire mystery of 'evil,' like nearly all other mysteries, has its origin in human ignorance; there would be no idea of it if all human beings were omniscient, because they would then clearly see that all their actions, mental and physical, are consequences of universal energy acting in agreement with comprehensive laws, and absolutely necessary under the circumstances." — "The Scientific Basis of Morality," by G. Gore.

"A favorite argument against free will is that if it be true, a man's murderer may as probably be his best friend as his worst enemy, a mother be as likely to strangle as to suckle her first-born, and all of us be as ready to jump from fourth-story windows as to go out of front doors, etc. Users of this argument should properly be excluded from debate till they learn what the real question is. 'Free will' does not say that everything that is physically conceivable is also morally possible. It merely says that of alternatives that really tempt our will more than one is really possible.

Of course, the alternatives that do thus tempt our will are vastly fewer than the physical possibilities we can coldly fancy. Persons really tempted often do murder their best friends, mothers do strangle their first-born, people do jump out of fourth-story windows." * * * "The indeterminism I defend, the free-will theory of popular sense based on the judgment of regret, represents that world as vulnerable, and liable to be injured by certain of its parts if they act wrong. And it represents their acting wrong as a matter of possibility or accident, neither inevitable nor yet to be infallibly warded off." — "The Dilemma of Determinism," by William James.

VI. Concerning the Relation between Ethics and Religion.

"If the infinite Spirit so communicates itself to the soul of man as to yield the idea of a possible perfect life, and that consequent sense of personal responsibility on the part of the individual for making the best of himself as a social being from which the recognition of particular duties arises, then it is a legitimate expression by means of metaphor — the only possible means, except action, by which the consciousness of spiritual realities can express itself — to say that our essential duties are commands of God. If again the self-communication of the infinite Spirit to the soul of man is such that man is conscious of his relation to a conscious being, who is in eternal perfection all that man has it in him to come to be, then it is a legitimate expression of that conscious relation by means of metaphor to say that God sees whether His commands are fulfilled by us or no, and an appropriate emotion to feel shame as in His presence for omissions or violations of duty incognizable by other men." — "Prolegomena to Ethics," by T. H. Green.

"A moral world order, a future life, and a moral world governor who assures the final triumph of goodness, are the assumptions to which we inevitably come when we attempt to think the moral problem through." — "The Principles of Ethics," by Borden P. Bowne.

"Our main reliance, then, for social progress must be on 'the law written on the heart,' the law of love accepted by reason and enforced by conscience. Religion can reinforce the power of the moral ideal, but it does this, not chiefly by offers of future rewards and threats of future punishments, but by setting before men, as the object of faith and worship, a God whose inmost nature is love." — "The Moral Order of the World," by Alexander Balmain Bruce.

"In their essential contents, religion and morality are wholly independent of each other. Religion, as we have seen, is a creed and a cult, a belief and form of worship, directed to the supernatural; morality is good will and conduct directed to the welfare of man, in some cases is nothing more than right social relations. Thus God is the object of one and man the object of the other. This single fact stamps them as distinct provinces." — "The Elements of Ethics," by James H. Hyslop.

"Some ask whether there can be any morality without religion. The question is ill expressed. It should be: Can the moral, be complete without the religious life? Experience proves that men can be just, honest, temperate, and sincere, without possessing piety. But is not the lack of piety in itself a lack of virtue, a diminution of the moral being? Should not the moral life express and contain the entire man in all his relations to God, as well as to men and to himself?" * * * "Religion is generally confounded with belief in the supernatural; but this is only the form of religion, not its essence." — "Theory of Morals," by Paul Janet.

"Religiös sind — so kann, glaube ich, allein geantwortet werden — alle diejenigen Vorstellungen und Gefühle, die auf ein ideales, den Wünschen und Forderungen des menschlichen Gemüthes vollkommen entsprechendes Dasein sich beziehen." — "Ethik," by Wilhelm Wundt.

"Haben wir uns aber mit Hilfe des Denkens auf unsere Stellung in der Existenz besonnen, haben wir eingesehen, dass wir mit all unserem Trachten, mit all unseren Plänen und all unseren Idealen als einzelne Glieder der grossen, unabsehbaren Reihe von Ursachen und Wirkungen dastehen, — so entsteht ein Gefühl des Lebens, nicht nur des Lebens, das sich in unserem eignen Organismus regt, sondern auch des Lebens, das sich im gesamten Universum regt, dessen Glieder wir sind. Unser Lebensgefühl wird durch den Lauf des Lebens und der Welt, soweit wir uns eine Vorstellung von demselben bilden können, erweitert und bestimmt. Es entsteht ein *kosmisches Lebensgefühl*, welches ein Analogon des organischen Lebensgefühls bildet." — "Ethik," by Dr. Harald Höffding.

"Wir werden vielmehr sagen: was immer für eine Ansicht von der Natur der Dinge jemand sich gebildet haben möge, die Gesetze der Moral behielten für ihn die gleiche Verbindlichkeit: sie seien eben nicht willkürliche Vorschriften, deren Befolgung durch die Rücksicht auf Lohn und Strafe seitens des Gesetzgebers geboten sei; veilmehr seien es Naturgesetze in dem Sinn, dass auf ihrer Befolgung die Wohlfahrt eines Lebens beruhe." — "System der Ethik," by Friedrich Paulsen.

"To view even the selfhood that passes away, even the deeds of the hour, as a service of God, and to regard the life of our most fragmentary selfhood as the divine life taking on human form, — this is of the deepest essence of religion." — "The World and the Individual," by Josiah Royce.

"I find that I undoubtedly seem to perceive, as clearly and certainly as I see any axiom in Arithmetic or Geometry, that it is 'right' and 'reasonable' for me to treat others as I should think that I myself ought to be treated under similar conditions, and to do what I believe to be ultimately conducive to universal Good or Happiness. But I cannot find inseparably connected with this conviction, and similarly attainable by mere reflective intuition, any cognition that there actually is a Supreme Being who will adequately reward me for obeying these rules of duty, or punish me for violating them. Or, more generally, I do not find in my moral consciousness any intuition, claiming to be clear and certain, that the performance of duty will be adequately rewarded and its violation punished." — "The Methods of Ethics," by Henry Sidgwick.

"God is the surety for morality — not in the gross and common meaning, that he stands ready to assure us the price and recompense, as though we feared we might make a fool's bargain by being virtuous gratuitously, but in the nobler and true sense, that his existence bears witness that we are not consecrating our lives to a chimera, or a dream of the imagination."— "Theory of Morals," by Paul Janet.

"Assuming that we at last have entered a period of the reverse movement, then the steady decline of the faith in the Christian God might lead us to infer with no small degree of probability that the human consciousness of guilt is, at this moment, likewise experiencing a considerable decline; indeed, the prospect cannot be rejected that the perfect and final triumph of atheism might altogether rid and quit mankind of this entire feeling of obligation to its beginning, its causa prima. Atheism and a kind of second innocence are parts of a whole." — "A Genealogy of Morals," by Friedrich Nietzsche.

"Morality without being backed by the rational intuition of religion would, indeed, have little chance of surviving all the weeds that threaten to choke it." — "The Rational or Scientific Ideal of Morality," by P. F. Fitzgerald.

"The attitudes of the moral and religious man are not merely unlike, but there is a certain conflict between the two. The reason of this will be apparent. When attention is turned in one of these directions, it is in some degree withdrawn from the other. I cannot at the same moment be conceiving of God as the only being of worth, and yet of my life — this fragmentary life — as itself a matter of worth. I alternate." * * * "When full of the thought of God, it is not impossible to allow a room to go dusty, a neighbor to be hungry, a bill to remain unpaid. Not impossible? It is dangerously natural. We shall be wise to warn ourselves, when thoughts of God are so dear and uplifting, that we must watch the little world which lies around us, and not, because of devoutness, neglect to hear its needy calls. * * * Morality fulfills itself in religion, even though its gaze is directed manward rather than Godward." — "The Field of Ethics," by George Herbert Palmer.

"Vollkommene Sittlichkeit ist identisch mit vollkommener Religiosität. Sie verlangt ein Leben in Gott, ein Verstehen seiner das Universum bewegenden Gedanken, wenigstens in dem Ausschnitt, welcher sich jedem in seiner individuellen Anschauung und Kenntnis der Welt darstellt." —"Das Problem der Ethik in der Gegenwart," by Hans Gallwitz.

"Will man ein persönliches Wesen anerkennen, welches die absolute Güte, Wahrheit und Schönheit an sich ist und Gott genannt wird: so kann der Vernunft das Recht dazu nicht bestritten werden; und dann ist Religion die Begeisterung für Gott. Wer aber eine solche Personificirung eines lebendigen Gottes der Güte, Wahrheit und Schönheit nicht bilden mag, also Atheist ist, der kann darum von der Anerkennung des Inhaltes des absoluten Wesens nicht entbunden werden: für ihn ist Religion die Begeisterung für ganz denselben Inhalt, aufgefasst in unpersönlicher Weise als das intelligible Reich der Humanität. 'Dein Reich komme' lautet des jüdischen und christlichen Gläubigen, wie des Atheisten; denn es ist dem Inhalte nach nur ein und dasselbe Reich." — "Allgemeine Ethik," by H. Steinthal.

"Si la devise de la science devant l'énigme des origines du monde est: Ignorabimus, la devise de la morale devant l'énigme des destinées du monde peut être: Sperabimus." — "Critique des Systémes de Morale," by Alfred Fouillée.

"Wir glauben uns zur Mitarbeit an dem Aufbau einer übersinnlichen Weltordnung berufen, und wie unklar uns auch der Plan der letzen und der Sinn unseres eignen Beitrags zu ihr bleiben mag, so fühlen wir doch, dass Alles, was uns als Pflicht erscheint, den letzten Grund seiner Verbindlichkeit darin hat, dass es nicht nur dem Begriff unserer thatsächlich vorhandenen Natur, sondern ihrer Bestimmung entspricht. Und diese Bestimmung liegt nicht mehr blos in einer Selbstentfaltung, die von rückwärts durch den Keim getrieben wird, sondern in der Bewegung nach einem Ziele zu, das uns vorwärts gesetzt ist." — "Mikrokosmus," by Lotze.

"Nehmen wir das Wort im üblichen Sinne, so zeigt die Erfahrung unwidersprechlich, dass Sittlichkeit ohne Religion möglich ist und ebenso Religion ohne Sittlichkeit. Und doch würde man sich taüschen, wollte man daraus den Schluss ziehen, dass beide Gebiete nichts mit einander zu thun haben." — "Sittliches Sein und sittliches Werden," by Ziegler.

"Religion im weitesten Sinn ist eine wesentliche Seite der ethischen Lebensauffassung. In der ächten Liebe, in der ächten Pflichterfüllung, in der ächten Hingabe an eine Berufsarbeit liegt Religion. Religion ist die Tilgung des einseitigen Individualismus, sie ist das Ich, das in einem grösseren Ganzen sich aufhebt; sie ist die vollendete Versöhnung alles Zwiespalts und Widerstreits. Darum, und zwar als die Seele jedes höhern Aufschwungs, haben die schönen Künste eine so hohe Bedeutung für die Ethik." — "Grundlegung der Ethik," by Carneri.

"Wir erkennen heut die deistische Ansicht des vorigen Jahrhunderts, nach welcher die Moral an die Ideentrias von Gott, Freiheit, und Unsterblichkeit geknüpft war, für einen überwundenen Irrthum; aber wir erkennen die entgegengesetzte Behauptung des subjectiven Idealismus, Materialismus und Skepticismus, dass die Moral von der Beschaffenheit der theoretischen Weltanschauung völlig unabhängig sei, noch entschiedener für einen Irrthum. * * * Die Phänomenologie des sittlichen Bewusstseins sich nicht vollenden kann, ohne sich durch eine Phänomenologie des religiösen

Bewusstseins zu ergänzen, und andererseits, die Religion nur dann einem geläuterten sittlichen Bewusstsein genugthun kann, wenn sie die Beziehung des Menschen zu Gott im Sinne der Wesensidentität beider, also unter dem Gesichtspunkt des concreten Monismus (und nicht unter dem des Theismus) auffasst." — "Phänomenologie des sittlichen Bewusstseins," by Eduard von Hartmann.

VII. Miscellaneous.

"Action is right, not because God wills it; but God wills the law as the expression of absolute right." — "Handbook of Moral Pailosophy," by Henry Calderwood.

"On the whole, we find that the progress of society depends less on education and the transmission of acquired characteristics from one generation to the next, than on a steady progress of elimination of inferior strains." — "The Origin and Growth of the Moral Instinct," by Alexander Sutherland.

"If in some distant planet lying were as esssential to human welfare as truthfulness is in this world, falsehood might there be a cardinal virtue." — "The Science of Ethics," by Leslie Stephen.

"Instead of admitting that there is in every case a right and a wrong, it may be contended that in multitudinous cases no right, properly so-called, can be alleged, but only a least wrong; and, further, it may be contended that in many of these cases where there can be alleged only a least wrong, it is not possible to ascertain with any precision which is the least wrong." — "The Data of Ethics," by Herbert Spencer.

"There is no scientific short-cut to the ascertainment of the right means to the individual's greatest happiness; every attempt to find a 'high priori road' to this goal brings us back ultimately to simple empiricism. For instead of a clear principle universally valid, we only get at best a vague and general rule, based on considerations which it is important not to overlook but the relative value of which we can only estimate by careful observation and comparison of individual experiences. Whatever uncertainty besets these processes must necessarily extend to all our reasonings about happiness. I have no wish to exaggerate these uncertainties, feeling that we must all continue to seek happiness for ourselves and for others, in whatever obscurity we may have to grope after it: but there is nothing gained by underrating them, and it is idle to argue as if they did not exist." — "The Method of Ethics," by Henry Sidgwick.

"No doubt or disproof of any existing theory can any more extinguish that self other than myself, which speaks to me in the voice of conscience, than doubt or disproof of the wave-theory of light can put out the noonday sun." — "Lectures and Essays," by William Kingdon Clifford.

" Besteht die individuelle Seele immer nur in der actuellen seelischen Thätigkeit, nicht in einem davon verschiedenen für sich existirenden Substrat, so ist damit von selbst die Berechtigung gegeben jenem Gesammtwillen keinen geringeren Grad von Realität zuzuschreiben als dem Individualwillen. Selbst die historische Continuität, die unser Bewusstsein mit demjenigen einer andern Zeit verbindet, besitzt genau so viel Wirklichkeit, als ihr im Bewusstsein zukommt. Vergangene und künftige Geschlechter leben mit uns wirklich ein Leben, nicht bloss scheinbar, wie dies der psychologische Atomismus annimmt. Cultur und Geschichte bilden ein wahres Gemeinleben, nicht bloss eine zufällige Resultante zahlloser Einzelbestrebungen, die sich nur äusserlich berühren und in ihren letzten Zielen weit auseinandergehen." — "Ethik," by William Wundt.

Issued August 21, 1903.

PUBLICATIONS.

The following publications of the Academy are offered for sale at the net prices indicated. Applications should be addressed to The Librarian, The Academy of Science of St. Louis, St. Louis, Mo.

TRANSACTIONS (in octavo).

Vol.	Number.	Price per number.	Price per vol.	Price in set.
1	1* 2† 3, 4	.... $4.00 2.00 each.	$7.50 (Nos. 2-4 only.)	$7.00 (Nos. 2-4 only.)
2	1 to 3	2.00 each.	5.50	5.00
3	1 to 4	2.00 each.	7.50	7.00
4	1 to 4	2.00 each.	7.50	7.00
5	1–2, 3–4	4.00 each. (double numbers)	7.50	7.00
6‡	1, 2, 6, 8, 10, 11, 16, 17 4, 5, 7, 13, 14, 15, 18 3, 9 12	25 cts. each. 50 cts. each. 75 cts. each. $1.00	7.50	7.00
7‡	2, 3, 4, 6, 7, 8, 13, 15, 16, 18, 19 5, 9 to 12, 14, 20 17 1	25 cts. each. 50 cts. each. 75 cts. $1.00	7.50	7.00
8‡	1, 3 to 6 8, 10, 12 2, 7, 9, 11	25 cts. each. 50 cts. each.	3.75	3.50
9‡	1, 3, 4, 7, 9 2, 5, 8 6	25 cts. each. 50 cts. each. $1.25	3.75	3.50
10‡	9 2, 4, 5, 10 1 3, 6, 7, 8, 11	10 cts. 25 cts. each. 40 cts. 50 cts. each.	3.75	3.50
11‡	2, 3 5–8, 10, 11 1 4 9	15 cts. each. 25 cts. each. 45 cts. 75 cts. 1.00	3.75	3.50
12‡	1, 9, 10 5 3, 8 2, 4, 6, 7	25 cts. each. 30 cts. 35 cts. each. 50 cts. each.	3.75	3.50

MEMOIRS (in quarto).

Contributions to the archaeology of Missouri, by the Archaeological Section. Part I. Pottery. 1880. $2.00.

The total eclipse of the sun, January 1, 1889. A report of the observations made by the Washington University Eclipse Party, at Norman, California. 1891. $2.00.

* Supply exhausted.

† Can be sold only to purchasers of the entire volume,— so far as this can be supplied.

‡ Each number is a brochure containing one complete paper (or rarely two).

Transactions of The Academy of Science of St. Louis.

VOL. XIII. No. 5.

THE LAW OF CONTRACTION OF GASEOUS NEBULAE.

FRANCIS E. NIPHER.

Issued October 1, 1903.

THE LAW OF CONTRACTION OF GASEOUS NEBULAE.

Francis E. Nipher.

In the discussion which follows it will be assumed that a nebulous mass of spherical form, is gravitating towards a central nucleus, and that the gas follows the law

$$Pv = CT. \tag{1}$$

At any point in the mass, the heat dQ, added to unit mass of volume v, under increasing pressure is,

$$dQ = C_v dT + Pdv \tag{2}$$

Let it be assumed that when thus subject to compression due to gravitation, the relation between pressure and specific volume is represented by the equation

$$Pv^n = \frac{P}{\delta^n} = A. \tag{3}$$

It is required to find the value of n. Eliminating P in (1) and (3),

$$v^{1-n} = \frac{C}{A} T$$

By differentiation

$$dv = v^n \frac{C}{A(1-n)} dT$$

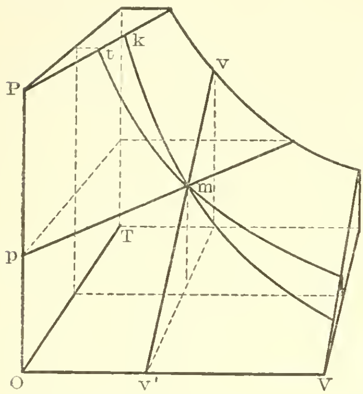
Combining this equation with (3)

$$Pdv = \frac{C}{1-n} dT. \tag{4}$$

Hence if this quantity be expressed in heat units, the specific heat of the gas will be

$$\frac{dQ}{dT} = C_v + \frac{C}{J(1-n)}. \tag{5}$$

Equation (3) may be considered as representing a projection on the P, v plane of a curve drawn on the thermodynamic surface P, v, T. The equation of this surface is (1), and its form is the well-known hyperbolic paraboloid shown in the figure.



Lines represented by (3), in the figure are m, v, a line of constant volume, for which $n = \infty$; m, κ, an isentropic line, for which $n = \frac{C_p}{C_v} = 1.41 = \kappa$; m, t, an isothermal line, for which $n = 1$; and m, p, a line of constant pressure, for which $n = o$. The projections of any of these lines, or of any line represented by (3) intermediate between these principal lines, on the three reference planes, are represented by the equations,

$$Pv^n = A \tag{3}$$

$$Tv^{n-1} = \frac{A}{C} \tag{6}$$

$$\frac{T^n}{P^{n-1}} = \frac{A}{C^n}. \tag{7}$$

For hydrogen, $C = 4.143 \times 10^7$ and $C_v = 2.420$. Putting these values in (5), together with the value of $J = 4.19 \times 10^7$, and the specific heat of hydrogen, for various values of n is computed as given in the following table. In the table the values of $\left(\frac{dQ}{dT}\right)_n$ are computed for compression only. For the same value of n in expansion, the sign of dT would be in every case reversed.

SPECIFIC HEAT OF HYDROGEN.

n	$\left(\frac{dQ}{dT}\right)_n$	
$+\infty$	$+2.420$	Vol. constant.
$+5$	$+2.173$	
$+4$	$+2.090$	
$+3$	$+1.925$	
$+2$	$+1.431$	
$+1.8$	$+1.184$	
$+1.6$	$+0.772$	
$+1.5$	$+0.442$	
$+1.41$	0.000	Entropy const.
$+\frac{4}{3}$	-0.547	
$+1.3$	-0.876	
$+1.2$	-2.525	
$+1.1$	-7.480	
$+1.0$	∞	Temp. const. sign of dT reverses.
$+0.8$	-7.365	
$+0.6$	-4.392	
$+0.4$	-4.068	
$+0.2$	-3.656	
0.0	-3.409	Pressure const.
-1.0	-2.915	
-2.0	-2.749	
-3.0	-2.667	
-4.0	-2.617	
-5.0	-2.584	
$-\infty$	-2.420	Vol. const. sign of n reverses.

The values of the table which lie between those for constant volume, and those for constant entropy, correspond to paths on the surface of the figure, lying in the angle v, m, κ. In these cases, pressure and temperature are increasing, volume is diminishing and heat is being added to the gas. The specific heat is positive. The specific heat becomes zero on the isentropic line m, κ, and between this line and the isothermal, m, t, the specific heat is negative. The temperature is rising, and heat is being taken from the gas. For isothermal compression, the specific heat is of course infinite. In the cases lying in the angle t, m, p, compression is still going on, but the temperature is falling, while heat is being removed from the gas. In the angle p, m, v', both temperature and pressure are falling, and the specific heat is still negative. It is evident that the gas at any point in a gravitating nebula, must be going through an operation which would be represented by a line in the figure lying within the angle κ, m, p. We shall make an attempt to locate this path.

At a distance R from the center or nucleus of a cosmical "gaskugel," where the density of the gas is $\delta = \frac{1}{v}$, the mass internal to R being M, the law of gravitation gives the equation

$$\frac{dP}{dR} = -k\frac{M}{R^2}\,\delta, \qquad (8).$$

where k is the gravitation constant.

By eq. (3) this becomes

$$\frac{dP}{dR} = -k\,\frac{M}{R^2}\left(\frac{P}{A}\right)^{\frac{1}{n}}.$$

Hence

$$M = -\left(\frac{A}{P}\right)^{\frac{1}{n}}\frac{R^2}{k}\frac{dP}{dR}.$$

By differentiation,

$$\frac{dM}{dR} = -\frac{A^{\frac{1}{n}}}{k}\left[\frac{R^2}{P^{\frac{1}{n}}}\,\frac{d^2P}{dR^2} + \frac{dP}{dR}\left(\frac{2P^{\frac{1}{n}}R}{P^{\frac{2}{n}}} - \frac{R^2P^{\frac{1-n}{n}}\frac{dP}{dR}}{nP^{\frac{2}{n}}}\right)\right]$$

By Geometry

$$\frac{dM}{dR} = 4\pi R^2\delta = 4\pi R^2\,\frac{P^{\frac{1}{n}}}{A^{\frac{1}{n}}}.$$

Equating these two values of $\frac{dM}{dR}$,

$$\frac{d^2P}{dR^2}+\frac{2}{R}\,\frac{dP}{dR}-\frac{1}{nP}\left(\frac{dP}{dR}\right)^2+\frac{4\pi k}{A^{\frac{2}{n}}}\;P^{\frac{2}{n}}=0\;\ldots\;(9)$$

This equation is satisfied by the primitive,

$$P=\left(\frac{4n-3n^2}{(2-n)^2}\,\frac{A^{\frac{2}{n}}}{2\pi kR^2}\right)^{\frac{n}{2-n}} \qquad (10).$$

Since $\qquad \delta=\left(\frac{P}{A}\right)^{\frac{1}{n}}=\frac{1}{v},$

$$\delta=\left(\frac{(4n-3n^2)\;A}{(2-n)^2\;2\pi kR^2}\right)^{\frac{1}{2-n}} \qquad (11).$$

By (6) and (11),

$$T=\frac{A^{\frac{1}{2-n}}}{C}\left(\frac{4n-3n^2}{(2-n)\;2\pi kR^2}\right)^{\frac{n-1}{2-n}} \qquad (12).$$

These three equations satisfy equations (1) (3) and (4). The mass internal to R is

$$M=4\pi\int_o^R R^2\delta dR.$$

Inserting δ from (11) and integrating,

$$M=4\pi\left(\frac{2-n}{4-3n}\right)\left(\frac{A\;(4n-3n^2)}{2\pi k\;(2-n)^2}\right)^{\frac{1}{2-n}}R^{\frac{4-3n}{2-n}}. \qquad (13)$$

The weight of a gramme at the surface of this mass is

$$g=k\,\frac{M}{R^2}=4\pi k\left(\frac{2-n}{4-3n}\right)\left(\frac{A(4n-3n^2)}{2\pi k(2-n)^2}\right)^{\frac{1}{2-n}}\frac{1}{R^{\frac{n}{2-n}}}. \qquad (14)$$

It will be observed that the value of P in (10), is

$$P = \int_R^\infty g\delta dR$$

where δ and g are given in (11) and (14).

If (12) be combined with (10), (11), (13), and (14), by the elimination of A, we have the equations,

$$P = \frac{4n - 3n^2}{(2-n)^2} \frac{C^2T^2}{2\pi kR^2} \tag{15}$$

$$\delta = \frac{4n - 3n^2}{(2-n)^2} \frac{CT}{2\pi kR^2} \tag{16}$$

$$M = \frac{n}{2-n} \frac{2CTR}{k} \tag{17}$$

$$g = \frac{n}{2-n} \frac{2CT}{R}. \tag{18}$$

If (13) be similarly combined with the other equations we have

$$P = \frac{4-3n}{8\pi n} \frac{M^2k}{R^4} \tag{19}$$

$$\delta = \frac{4-3n}{4\pi(2-n)} \frac{M}{R^3} \tag{20}$$

$$T = \frac{2-n}{nC} \frac{Mk}{2R} \tag{21}$$

$$g = \frac{Mk}{R^2} \tag{22}.$$

Equations (17) and (21) are of course identical.

In equations (15) to (18), the values P, δ, and g, are values of these quantities at a distance R from the center. M is the mass internal to the spherical surface of radius R.

According to these equations the density and pressure are infinite at the center of the mass. This is, however, the value at a single point. At any small finite distance from the center, both are finite. Of course the gaseous matter at and immediately around the center is, or may be, also liquid and solid. There may be no dividing surface between solid, liquid and gas, by reason of the enormous pressures in the central part of the nebula.

By inspection of equations (19) (20) and (21), it will be observed that, entirely irrespective of the value of n,

$$\frac{P}{\delta^{\frac{4}{3}}} = Pv^{\frac{4}{3}} = B \tag{23}$$

$$\frac{T}{\delta^{\frac{4}{3}-1}} = Tv^{\frac{1}{3}} = \frac{B}{C} \tag{24}$$

$$\frac{T^{\frac{4}{3}}}{P^{\frac{4}{3}-1}} = \frac{T^{\frac{4}{3}}}{P^{\frac{1}{3}}} = \frac{B}{C^{\frac{4}{3}}} \tag{25}$$

where

$$B = \frac{k}{2n}\left(\frac{4\pi}{4-3n}\right)^{\frac{1}{3}}(2-n)^{\frac{4}{3}} M^{\frac{2}{3}} \tag{26}$$

By eq. (17) this equation may also be written

$$B = \left(\frac{2\pi k}{(4-3n)n}\right)^{\frac{1}{3}}\Big((2-n)CTR\Big)^{\frac{2}{3}}.$$

The product CTR is constant at the surface of any constant mass forming the core of a gaskugel, as eq. (17) shows, whatever may be the gas of which it may be composed, and whatever may be the radius of the contracting core.

These equations should be compared with (3), (6) and (7). These equations involve the relation between P, δ and T, at the surface of any fixed mass forming the core of a gravitating gaskugel, the pressure being due to the alleged attraction of this core for the superposed layers. Equations (3), (6) and (7), involve no such conditions.

If we assume that the mass M has initially a radius R_o, and that it contracts to a radius R, so that $R_o = \rho R$, then the two equations for P will be

$$P_o = \frac{4 - 3n}{8\pi n} \quad \frac{M^2 k}{R_o^4}$$

$$P = \frac{4 - 3n}{8\pi n} \quad \frac{M^2 k}{R^4}$$

Hence

$$\frac{P_o}{P} = \left(\frac{R}{R_o}\right)^4$$

or

$$P = \rho^4 \; P_o. \qquad (26a)$$

In a similar way it may be shown that

$$\delta = \rho^3 \delta_o \qquad (27)$$

and

$$T = \frac{T_o}{\rho}. \qquad (28)$$

In Ritter's well-known paper of 1878* he established the relations involved in the last three equations, by an ingenious train of reasoning. He assumes a gravitating weltkugel to so contract, that any and every linear distance has become $\frac{1}{m}$ of its original value. Then the volume of unit mass at any point, in terms of the initial volume, is

$$v = \frac{v_o}{m^3}.$$

By reason of this contraction, the gravitational pull on each

* Annalen der Physik und der Chemie. Bd. V, S. 549–50.

and every unit mass has been multiplied by m^2. Each unit mass may be supposed to lie as a piston in a fixed radial cone. After the piston descends, its area becomes $\frac{1}{m^2}$ of its initial value. The force per unit area, due to the weight of superposed layers, becomes m^4 times as great, or

$$P = m^4 P_o.$$

The product Pv has therefore become m times as great as it was in the initial stage. Therefore by the equation $Pv = CT$

$$T = mT_o.$$

Eliminating m in these equations Ritter obtained equations corresponding exactly to (23) (24) and (25), viz.:

$$Pv^{\frac{4}{3}} = P_o v_o^{\frac{4}{3}}; \quad Tv^{\frac{1}{3}} = T_o v_o^{\frac{1}{3}} \text{ and } \frac{T^4}{P} = \frac{T_o^4}{P_o},$$

but he did not determine the values of these constants, as is done in (26). Ritter saw very clearly, however, that these three equations were characteristic of a gravitating mass in equilibrium under its own forces, as distinguished from the case where a few grammes of gas are held in the cylinder of a heat engine. In the latter case the gas may be compressed and cooled or heated in any way that can be imagined. The value of n in eq. (3) may be anything between $+\infty$ and $-\infty$, and the range in specific heat will be as wide as that of n, as is shown in the table at the beginning of this paper. He concluded that his equations, last given, were the projections on the three reference planes, of the path on the surface represented by eq. (1), traced by a point representing the changing condition of any unit mass in his gravitating gaskugel. Ritter therefore concludes that the value of n in eq. (3) is $\frac{4}{3}$ and computes the specific heat of gravitational contraction as follows: —

By a well-known equation

$$dQ = \frac{C_v}{C}\, vdP + \frac{C_P}{C}\, Pdv.$$

From the equation of a perfect gas,

$$dT = \frac{1}{C}\, vdP + \frac{1}{C}\, Pdv.$$

Hence for the specific heat

$$\frac{dQ}{dT} = \frac{C_v \frac{dP}{P} + C_P \frac{dv}{v}}{\frac{dP}{P} + \frac{dv}{v}} \qquad (29).$$

From eq. (3)

$$\frac{dP}{P} = - n \frac{dv}{v}.$$

This equation in (29) gives

$$\frac{dQ}{dT} = \frac{C_P - nC_v}{1 - n} = \frac{C_P}{\kappa}\left(\frac{\kappa - n}{1 - n}\right), \qquad (30)$$

where $\kappa = \frac{C_P}{C_v} = 1.41.$

Assuming $n = \frac{4}{3}$ Ritter obtains

$$\frac{dQ}{dT} = - 0.16312\ C_P \qquad (31).$$

For hydrogen $C_P = 3.409$, which gives

$$\frac{dQ}{dT} = - 0.547.$$

This is of course the value for specific heat given in the table for $n = \frac{4}{3}$.

The values called for in (29) may also be found from equations of this paper. From eqs. (10) and (11), where P and $\delta = \frac{1}{v}$ are given in terms of R, as will be seen,

$$\frac{dP}{P} = -\frac{2n}{2-n}\frac{dR}{R}$$

$$\frac{dv}{v} = \frac{2}{2-n}\frac{dR}{R}.$$

These values, in eq. (29) give eq. (30). This equation is the same as (5) as may be easily seen by equating the values. But all of this leaves the value of n wholly undetermined. If the value $n = \frac{4}{3}$ which Ritter assumed, be substituted in (19) and in various other equations containing the factor $4 - 3n$, the co-efficients in n reduce to zero. This value of n calls for an impossible distribution of matter, in a gravitating nebula. This will be pointed out more fully as we proceed.

What we have done is to assume the general relation $Pv^n = A$. We find as a consequence, that at the surface of any fixed mass M, forming the core of a gravitating gaskugel, (eq. 26)

$$Pv^{\frac{4}{3}} = \frac{k}{2n}\left(\frac{4\pi}{4-3n}\right)^{\frac{1}{3}}(2-n)^{\frac{4}{3}} M^{\frac{2}{3}}.$$

How can this result justify the assumption that $n = \frac{4}{3}$ for such a gravitating mass?

This matter has been under consideration for several years, and it was only recently observed, that n could be computed by an independent method, as will now be explained.

By a well-known equation, the specific heat along any path determined by n is

$$\left(\frac{dQ}{dT}\right)_n = C_P - \frac{T}{J}\left(\frac{dv}{dT}\right)_P\left(\frac{dP}{dT}\right)_n. \qquad (32)$$

This equation assumes expansion of the gas, with the addition of heat. To correspond to eq. (5) the sign of dQ must be reversed.

If eqs. (19) and (21) be combined by the elimination of R, the value of $\left(\frac{dP}{dT}\right)_n$ may be found at any of the concentric spherical surfaces in a contracting gaskugel.

That value is

$$\left(\frac{dP}{dT}\right)_n = \frac{8n^3C^4(4-3n)T^3}{\pi k^3M^2(2-n)^4}.$$

By (21)

$$T = \frac{2-n}{nC}\,\frac{Mk}{2R}.$$

By differentiating (16) with R constant,

$$\left(\frac{dv}{dT}\right)_P = -\frac{2\pi k(2-n)^2R^2}{n(4-3n)CT^2}.$$

These values in (32), by further substitution from (17) give (reversing the sign of dQ)

$$\left(\frac{dQ}{dT}\right)_n = -C_P - \frac{4C}{J} \qquad (33).$$

This is the specific heat at any point in a gravitating gaskugel, in terms wholly independent of n. If this value be equated with (5), the value of n is found to be

$$n = \frac{2C_P + 4\dfrac{C}{J}}{2C_P + 3\dfrac{C}{J}} \qquad (33a).$$

The value of n for various gases is computed in a table. It seems to be a constant.

Gas	C_P	C	$2C_P + 3\frac{C}{J}$	$2C_P + 4\frac{C}{J}$	n
H	3.409	4.13×10^7	9.775	10.761	1.101
N	0.2438	2.97×10^6	0.700	0.7712	1.101
O	0.2175	2.59×10^6	0.621	0.6830	1.100
Air	0.2375	2.88×10^6	0.681	0.7498	1.101

If eq. (33a) be solved for C_P we have

$$C_P = \frac{C}{J}\,\frac{3n - 4}{2 - 2n}.$$

From the equations of a gas we have $C_P - C_v = \frac{C}{J}$; and $C_P = \kappa C_v$. Hence

$$C_P = \frac{C}{J}\,\frac{\kappa}{\kappa - 1}.$$

These two equations give for n,

$$n = \frac{6\kappa - 4}{5\kappa - 3}. \qquad (33b)$$

The value of the specific heat of hydrogen for gravitational contraction is from (33)

$$\left(\frac{dQ}{dT}\right)_n = -\ 7.365.$$

Ritter's value computed from his equation is as before stated: —

$$\left(\frac{dQ}{aT}\right)_n = -\ 0.547.$$

If the value of n determined in (33*b*) be substituted for the value $\frac{4}{3}$, in Ritter's equation (30), of this paper, his result will also be — 7.365.

The coefficients and exponents involving n in the equations which precede, may now all be written in terms of κ but nothing is gained by doing so. They are very interesting in form, but they are no more simple than those involving n. If we replace n by the value 1.1, equations (10) to (14) become

$$P = \left(\frac{0.95 A^{1.82}}{2\pi k R^2}\right)^{1.22} \qquad (10)'$$

$$\delta = \left(\frac{0.95 A}{2\pi k R^4}\right)^{1.11} \qquad (11)'$$

$$T = \frac{A^{1.11}}{C}\left(\frac{0.95}{2\pi k R^2}\right)^{0.111} \qquad (12)'$$

$$M = 5.14\pi \left(\frac{0.95 A}{2\pi k}\right)^{1.11} R^{0.77} \qquad (13)'$$

$$g = 5.14\pi k \left(\frac{0.95 A}{2\pi k}\right)^{1.11} \frac{1}{R^{1.22}} \qquad (14)'.$$

In these equations, the value of the gravitation constant k is $\frac{1}{1.543 \times 10^7}$. The radius R is to be measured in *cm*. A is of course determined by eq. (3), for any assumed locus. Equations (15) to (18) become

$$P = 0.95 \, \frac{C^2 T^2}{2\pi k R^2} \qquad (15)'$$

$$\delta = 0.95 \, \frac{C T}{2\pi k R^2} \qquad (16)'$$

$$M - 1.22 \, \frac{2 C T R}{k} \qquad (17)'$$

$$g = 1.22 \frac{2CT}{R} \tag{18$'$}$$

Equations (19) to (22) become

$$P = \frac{0.636}{8\pi} \frac{M^2 k}{R^4} \tag{19$'$}$$

$$\delta = \frac{0.78}{4\pi} \frac{M}{R^3} \tag{20$'$}$$

$$T = \frac{0.818\, Mk}{2\, CR} \tag{21$'$}$$

$$g = \frac{M\,k}{R^2} \tag{22$'$}$$

Equation (23) also becomes (see (26)),

$$Pv^{\frac{4}{3}} = 1.034\, kM^{\frac{2}{3}}\,. \tag{23$'$}$$

Equations (24) and (25) need not be rewritten.

The work done in compressing a mass M, from an infinite volume to a sphere having a radius R is

$$W = 4\pi \int^{\infty} R^2 P dR.$$

The value of P being obtained from (19) this integral is

$$W = \frac{4 - 3n}{n} \frac{M^2 k}{2R} \tag{34}$$

$$= 0.636\, \frac{M^2 k}{2R}\,.$$

If an isothermal distribution of temperature were possible during the compression, n would be unity and the coefficient in n would also be unity. Since $\frac{M}{\sqrt{k}}$ is the mass, in astronomical units of 3928 grammes, the expression would then be precisely like the one for the compression of an electrified spherical surface having a charge numerically equal to $\frac{M}{\sqrt{k}}$.

It may be of interest to point out that if V represents the resulting volume of the sphere

$$PV = \frac{4}{3}\pi R^3 \times P = \frac{4 - 3n}{3n}\,\frac{M^2 k}{2R}.$$

This is $\frac{1}{3}$ of the work represented in (34).

Equation (20) enables us to determine the average density δ_a of the mass M at any time during compression.

We have

$$M = \frac{4}{3}\pi R^3 \delta_a = 4\pi \frac{2 - n}{4 - 3n}\,\delta R^3$$

$$\delta_a = 3\,\frac{2 - n}{4 - 3n}\,\delta = 3.86\,\delta. \qquad (35)$$

If n were $\frac{4}{3}$ the average density would be infinite.

To find where in the sphere, the gas would have average density, we have from eq. (11),

$$\frac{B'}{R_a^{\frac{2}{2-n}}} = 3\,\frac{2 - n}{4 - 3n}\,\frac{B'}{R^{\frac{2}{2-n}}}$$

where B' is the constant coefficient in (11). Hence

$$R_a = \left(\frac{4 - 3n}{3(2 - n)}\right)^{\frac{2-n}{2}} R = 0.545\ R. \qquad (36)$$

If n were $\frac{4}{3}$ the average density would be at the center.

The average pressure within radius R may be found by substituting P from eq. (10) in the equation

$$P_a = \frac{4\pi \int_o^R R^2 P dR}{4\pi \int_o^R R^2 dR} = 3 \frac{2-n}{6-5n} P. \qquad (37)$$

It is to be observed that if n were as large as 1.2 the average pressure within the mass M would be infinite. Making $n = 1.1$ the average pressure is found to be 5.4 P.

By (10) the average pressure is distant from the center of mass

$$R_a = \left(\frac{1}{3}\frac{6-5n}{2-n}\right)^{\frac{2-n}{2n}} R = 0.502\ R. \qquad (38).$$

If $n = 1.2$ the average pressure would be at the center. It is therefore clear that n must be less than 1.2 in order that the distribution may be physically possible. The value with $n = 1.1$ is given above. It locates the gas of average pressure almost exactly midway between the center and the spherical surface of radius R.

The average temperature, deduced in the same way from (12), is

$$T_a = 3\frac{2-n}{8-5n} T = 1.08\ T. \qquad (39)$$

The distance from the center to the surface having this temperature is

$$R_a = \left(\frac{1}{3}\frac{8-5n}{2-n}\right)^{\frac{2-n}{2(n-1)}} R = 0.707\ R. \qquad (40)$$

These values in T are very interesting. They show that while the average temperature within any concentric spherical surface is but little above the temperature at the surface, the gas has this average temperature at a distance $0.707R$ from the center. It will also be observed that if the temperature were uniform throughout the mass, or $n = 1$, the value of R_a computed from the above equation would be $1^{\infty} R$. This, of course, means that the average temperature would be anywhere between 0 and R.

Ritter computes the ratio of the heat per unit mass radiated from the nebula during contraction from a condition P_o, v_o, T_o, to a condition P, v, T, to the total work done on this unit mass during the same operation. Both quantities are measured in heat units. He finds the ratio to be

$$\frac{Q}{W} = 0.187.$$

According to this only 18.7% of the heat developed by the work done on each unit mass, is radiated. The remainder of the heat goes to raise the temperature of the mass. By the equations of this paper, the heat radiated is (28), (33),

$$\begin{aligned} Q &= \left(\frac{dQ}{dT}\right)_n (T - T_o) \\ &= -\left(Cp + 4\frac{C}{J}\right)(T - T_o) \\ &= -\left(Cp + 4\frac{C}{J}\right) T_o (\rho - 1) \qquad (41). \end{aligned}$$

The work done on unit mass in the same operation is (since $P_o v_o^n = P v^n$)

$$W = \int P dv = P_o v_o^n \int_{v_o}^{v} \frac{dv}{v^n}$$

$$= \frac{P_o v_o}{n-1}\left(1-\rho\right) = -\frac{C T_o}{J\,(n-1)}\,(\rho-1).$$

By (5) and (33) this becomes

$$W = -\left(C_v + C_P + \frac{4C}{J}\right) T_o\,(\rho-1). \qquad (42)$$

Hence

$$\frac{Q}{W} = \frac{C_P + 4\,\frac{C}{J}}{C_v + C_P + 4\,\frac{C}{J}} = \frac{C_P + 4\,\frac{C}{J}}{2\,C_P + 3\,\frac{C}{J}} = 0.75. \qquad (43)$$

According to this equation, the heat radiated is 75% of the heat equivalent to the work of compression, and not 18.7%, as Ritter found. Only 25% of the energy of compression is used in causing a rise of temperature.

The same result may be obtained from Ritter's equation (80), p. 554, by making his value $\epsilon = 1.1$ instead of $\frac{4}{3}$.

The numerator of (43) is the specific heat of gravitational compression as determined in (33). It is evident that $W - Q$ must be the heat applied to the unit mass of gas, and causing a rise of temperature. By (43)

$$\frac{Q}{W-Q} = \frac{C_P + 4\,\frac{C}{J}}{C_P - \frac{C}{J}} = \frac{C_P + 4\,\frac{C}{J}}{C_v} = 3.0. \qquad (44)$$

This result deduced in (44) is exactly what we know to be true. Equations (43) and (44) assert that for a rise of temperature of 1° C., energy equivalent to $2\,C_P + 3\,\frac{C}{J}$ heat units is applied to the unit mass, of which $C_P + 4\,\frac{C}{J}$ heat units are radiated, and $C_P - \frac{C}{J} = C_v$ heat units are used in raising the temperature.

The ratio $\frac{Q}{W}$ is computed for various gases which conform closely to eq. (1) at high temperatures. The results are given in the annexed table. The fifth column gives the specific heat of gravitational compression represented in eq. (33).

Gas	C_P	C	$2C_P + 3\frac{C}{J}$	$C_P + 4\frac{C}{J}$	$\frac{Q}{W}$
H	3.409	4.13×10^7	9.775	7.352	0.75
N	0.2438	2.97×10^6	0.700	0.5274	0.75
O	0.2175	2.60×10^6	0.621	0.4655	0.75
Air	0.2375	2.88×10^6	0.681	0.5123	0.75

It will be observed that this ratio is constant for all these gases. Representing this ratio by c we have by (43)

$$C_P = \frac{C}{J}\,\frac{4-3c}{2c-1}. \tag{45}$$

From the equations $C_P - C_v = \frac{C}{J}$ and $C_P = \kappa C_v$ we have

$$C_P = \frac{C}{J}\,\frac{\kappa}{\kappa-1}. \tag{46}$$

Hence by (45) and (46)

$$c = \frac{5\,\kappa - 4}{5\,\kappa - 3} = 0.753. \tag{47}$$

Also from (43) and (47)

$$\frac{W-Q}{W} = \frac{1}{5\,\kappa - 3} = 0.247. \tag{48}$$

If we consider only that part of the heat energy which is applied to the mass M, of radius R we may also write an equation involving a specific heat. It is not the specific heat of the operation, but a specific heat s in a more restricted sense. Let T_a represent the average temperature of the mass M. Then by (48) and (34),

$$Ms\,T_a = \frac{1}{5\,\kappa - 3}\ \frac{4 - 3n}{n}\ \frac{M^2\,k}{2\,JR}. \qquad (49)$$

Replacing T_a by its value in (39) and M by its value in (21)

$$s = \frac{(8 - 5n)\ (4 - 3n)}{3\ (2 - n)\ (5\kappa - 3)}\ \frac{2\,C}{J} \qquad (50)$$

$$= 0.331\ \frac{C}{J}.$$

If there existed a series of nebulae, of various pure gases, like those represented in the last table, we might suppose that they had each advanced to such a stage, that each had the same mass M within a sphere of the same radius, R. Equation (21) asserts that the product CT would then be constant for the series. Those having a larger constant C, would have a correspondingly smaller temperature T, or T_a. This is also the meaning of eq. (50).

This also follows from equations (19) and (20). Under the conditions just assumed, both P and δ would be constant for the series. As a consequence from eq. (1) the product CT must be a constant for all gases.

To show the extent to which our own sun has, in its last days, of thermal decrepitude, departed from the gaseous condition, we may compare its mass, as computed from eq. (17)′, with that obtained from observation. We have for hydrogen, $C = 4.14 \times 10^7$, $R = 6.97 \times 10^{10}\ cm$, $\frac{1}{k} = 1.54 \times 10^7$, and T at the surface of the sun may be taken as 10000°C. This gives for M the value 1.08×10^{30} grammes. Taking the mass of the earth at 6.14×10^{27} grammes, and the mass of the sun as 3.549×10^5 times that of the earth, the mass of the sun is 2.18×10^{33} grammes. This is about 2000 times the mass computed from (17)′.

The conditions here discussed, may perhaps be brought about in some such way as this. An infinitely diffused mass of gas occupies an infinite space. It is surrounded by an infinite series of infinite spaces, having perhaps an increasingly higher order of magnitude. A great meteorite, or a world, strays into the nebula, and probably sets it into rotation. The nebulous mass gravitates towards the solid nucleus, which has been already slightly warmed by frictional contact with the diffused gas. As the gravitating action continues, the temperature rises, and the solid mass, while still remaining solid, becomes also a liquid and a gas. The bounding surface between solid and gas has disappeared. How else can gaseous pressure develop in an infinitely diffused mass of gas having a temperature at which all gases are solid?

This pressure thus developed, is automatically applied in a perfectly definite way, as radiation and contraction proceed. If, as the temperature rises, the heat radiates more and yet more rapidly, the operation is thereby hastened, but the law of contraction remains unchanged. The relations between P, δ, and T must remain invariable.

These equations are now in condition to be linked with the solar radiation constant, and the time element. They may thus serve to permit a re-examination of the history of the evolution of the solar system.

Issued October 1, 1903.

PUBLICATIONS.

The following publications of the Academy are offered for sale at the net prices indicated. Applications should be addressed to The Librarian, The Academy of Science of St. Louis, St. Louis, Mo.

TRANSACTIONS (in octavo).

Vol.	Number.	Price per number.	Price per vol.	Price in set.
1	1* 2† 3, 4	.... $4.00 2.00 each.	$7.50 (Nos. 2–4 only.)	$7.00 (Nos. 2–4 only.)
2	1 to 3	2.00 each.	5.50	5.00
3	1 to 4	2.00 each.	7.50	7.00
4	1 to 4	2.00 each.	7.50	7.00
5	1–2, 3–4	4.00 each. (double numbers)	7.50	7.00
6‡	1, 2, 6, 8, 10, 11, 16, 17 4, 5, 7, 13, 14, 15, 18 3, 9 12	25 cts. each. 50 cts. each. 75 cts. each. $1.00	7.50	7.00
7‡	2, 3, 4, 6, 7, 8, 13, 15, 16, 18, 19 5, 9 to 12, 14, 20 17 1	25 cts. each. 50 cts. each. 75 cts. $1.00	7.50	7.00
8‡	1, 3 to 6 8, 10, 12 2, 7, 9, 11	25 cts. each. 50 cts. each.	3.75	3.50
9‡	1, 3, 4, 7, 9 2, 5, 8 6	25 cts. each. 50 cts. each. $1.25	3.75	3.50
10‡	9 2, 4, 5, 10 1 3, 6, 7, 8, 11	10 cts. 25 cts. each. 40 cts. 50 cts. each.	3.75	3.50
11‡	2, 3 5–8, 10, 11 1 4 9	15 cts. each. 25 cts. each. 45 cts. 75 cts. 1.00	3.75	3.50
12‡	1, 9, 10 5 3, 8 2, 4, 6, 7	25 cts. each. 30 cts. 35 cts. each. 50 cts. each.	3.75	3.50

MEMOIRS (in quarto).

Contributions to the archaeology of Missouri, by the Archaeological Section. Part I. Pottery. 1880. $2.00.

The total eclipse of the sun, January 1, 1889. A report of the observations made by the Washington University Eclipse Party, at Norman, California. 1891. $2.00.

* Supply exhausted.

† Can be sold only to purchasers of the entire volume,— so far as this can be supplied.

‡ Each number is a brochure containing one complete paper (or rarely two).

Transactions of The Academy of Science of St. Louis.

VOL. XIII. No. 6.

A NEW METHOD FOR THE DETERMINATION OF FREE LIME, AND ON SO-CALLED DEAD BURNT LIME.

EDWARD H. KEISER AND S. W. FORDER.

Issued December 4, 1903.

A NEW METHOD FOR THE DETERMINATION OF FREE LIME, AND ON SO-CALLED DEAD BURNT LIME.*

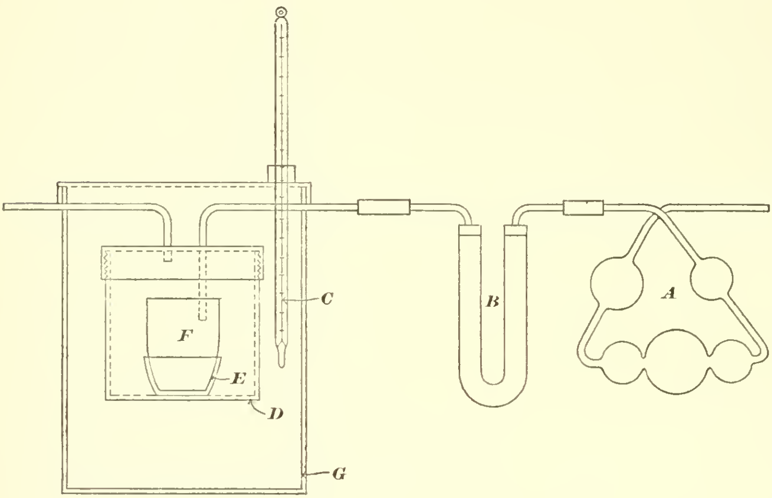
Edward H. Keiser and S. W. Forder.

A great many attempts have been made to devise a quantitative method for the determination of free lime in Portland cements, basic phosphate slags, commercial quick lime and similar substances but none of the methods thus far proposed have been satisfactory, nor have any of them come into general use. The difficulty is that in the substances mentioned, besides the free lime there are basic lime compounds, such as the basic di and tricalcium silicates which are decomposed by water with the formation of calcium hydroxide. When these substances are treated with aqueous solutions, as, for example, sugar solution, for the purpose of dissolving the free lime, the water of the solution at once acts upon the basic lime compounds and forms calcium hydroxide. It is, therefore, impossible to determine how much of the lime that is found was in combination and how much was in free condition.

The method described below depends upon the fact that uncombined lime, that is, free lime, combines almost instantly with water whereas the basic calcium silicates are acted upon much more slowly by water. The process is carried out as follows: A weighed quantity of the substance, .2 to .5 grams in a platinum crucible is first heated to drive off moisture, or, in the case of cements, is heated with the blast lamp for a few minutes to expel any carbon dioxide, and after cooling in a desiccator is again weighed. A few drops of distilled water, which has been recently boiled, are then added and the crucible placed in the brass protector *D*, shown in the figure. (*D* is simply a cylindrical box provided with a

* Presented to The Academy of Science of St. Louis, October 19, 1903.

screw top carrying a brass inlet and outlet tube. The thread of the cap is made air tight with a little white lead and oil.) The protector is put into the air bath and the temperature is raised to 85 degrees C. and allowed to remain at about this point for 20 minutes. Then a slow current of air is drawn through the apparatus and the temperature raised to 185 degrees. The air is freed from carbon dioxide and moisture by passing through the potash bulb and calcium chloride tube *A* and *B* as shown in the figure. After drying in this way for 30 minutes the apparatus is disconnected, the protector removed from the air bath and the crucible taken out and



placed in a desiccator and when cold is weighed. The increase of weight is the weight of water taken up by the quick line to form calcium hydroxide.

The method and apparatus was first tested by hydrating pure lime obtained by the ignition of Iceland spar. A weighed quantity of Iceland spar was heated from 5 to 10 minutes in a platinum crucible with the blast lamp. After cooling in a desiccator the weight of quick lime was determined. The hydration was then carried out as above described. The following results were obtained: —

Weight of Lime taken.	Weight of Water absorbed.	Weight of Lime found.	Per cent of Lime found.
.2239	.0724	.2252	100.60
.3287	.1049	.3263	99.26
.2368	.0757	.2355	99.45
.2799	.0909	.2828	101.00
.5322	.1704	.5300	99.60
.1579	.0507	.1577	99.90
.1810	.0581	.1807	99.88
.2425	.0852	.2433	100.30
.2487	.0794	.2470	99.33

These results show that the method is quantitative and that lime that has been heated to the highest temperature attainable in a platinum crucible with the blast lamp is completely slaked in twenty minutes at 85 degrees. In fact in the case of pure quick lime the slaking is very rapid. The calcium hydroxide was found to be constant in weight up to 250 degrees, beyond which it was not tested. The calcium hydroxide when exposed to the air, of course takes up carbon dioxide. It is, therefore, necessary to keep the crucible in a desiccator containing caustic potash instead of calcium chloride and to weigh as rapidly as possible.

HYDRATION OF COMMERCIAL LIME.

For the determination of calcium oxide in commercial quick lime a large piece was taken and the exterior portions broken away and a sample for analysis taken from the interior of the lump. This was quickly placed in a tightly stoppered weighing tube. Portions of this were weighed off in a platinum crucible and then water was added in a little greater quantity than was necessary for slaking, the crucible put into the protector warmed to 85 degrees for some minutes and then a slow current of air free from carbon dioxide drawn through for half an hour, the temperature now being raised to 185 degrees. After cooling in the desiccator the increase in weight was determined and from this the percentage of lime in the sample calculated. The following results were thus obtained: —

Per Cent of H_2O.	Per Cent of CaO, Calculated.
29.11	90.56
29.21	90.88
28.98	90.20

This same specimen of quick lime after ignition over the blast lamp and immediate hydration gave the following: —

Per Cent of Water taken up.	Per Cent of Lime by Calculation.
32.30	100.50
32.36	100.70

Thus showing the extent to which the lime had been acted upon by the moisture and carbon dioxide of the air.

The method is also well adapted for rapidly determining the value of limestones for the purpose of making quick lime. Thus a small quantity of the limestone is weighed in a platinum crucible then ignited with the blast lamp and after weighing the quick lime is hydrated by this method. From the weight of water taken up the per cent of lime is calculated. The first series of determinations given above show what results would be obtained with a pure limestone such as Iceland spar or calcite. The following determinations were made with a siliceous dolomite from Arkansas: —

Weight of Dolomite.	Weight of Water taken up.	Per Cent of Lime.
.2974	.0137	14.33
.2896	.0134	14.40

HYDRATION OF DEAD BURNT LIME.

It is generally believed by practical men that lime that has been very highly heated becomes dead burnt or inert to water. Statements to this effect are found in chemical literature. Thus Dammer, Handbuch der Anorganischen Chemie, II, 2, 294, states that very high temperatures must be avoided in the preparation of lime, especially if impure calcium carbonate is used, because the lime at too high temperatures becomes dead burnt, that is, it becomes incapable of uniting with water. Zulkowski, Chemische Industrie, 1901, page 290, maintains that a portion of the lime in Portland cements is in this dead burnt condition. In an article in the Thonindustrie Zeitung, 1902, the same author suggests the formula

$\mathrm{Ca}\genfrac{}{}{0pt}{}{\diagup \mathrm{O} \diagdown}{\diagdown \mathrm{O} \diagup}\mathrm{Ca}$ for dead burnt lime.

For the purpose of determining the behavior of highly heated lime towards water, powdered Iceland spar was placed between the carbon pencils of an electric arc and the current passed for one hour. A number of particles of semi-fused lime were thus obtained. These particles were carefully separated from the powder that had not melted, and weighed quantities were hydrated by the above described method. It was found that this lime that had been heated in the electric arc slaked more slowly than that which had not been heated to so high a temperature, but still it combined slowly with water at ordinary temperatures and on allowing it to stand with water at the ordinary temperature for 24 hours it had slaked completely. When the temperature was raised to 85 degrees, the slaking was complete in two hours. The following results were obtained: —

Wt. of Lime taken.	Wt. of Water taken up.	Per Cent of Lime calculated from Water.
.2799	.0909	101.0
.2050	.0661	100.3
.5322	.1704	99.6
.3909	.1279	101.0

Another specimen of lime that had been heated with the oxy-coal gas blowpipe gave the following result: —

.3557	.1163	100.5

These experiments show that pure lime that has been heated to very high temperatures, even semi-fused lime is not inert to water and that it slakes comparatively rapidly if the water is warm. That the slaking with cold water is slower than in the case of ordinary lime may be due to the fact that lime that has been heated to very high temperatures is much more compact and less porous than the ordinary lime. The surface exposed to the action of water being much less the time required for slaking would necessarily be greater. We see from these experiments that pure lime cannot be made inert to water by heating to high temperatures. The inertness of commercial lime is probably due to the presence of compounds of silica and iron oxide with the lime which are decomposed very slowly by the water.

HYDRATION OF CALCIUM SILICATES.

The hydration of lime and its compounds was further studied by making synthetically the compounds that are assumed to be present in Portland cement, and then hydrating these substances by this method. Pure lime and silica were mixed in molecular quantities so as to give when fused the compounds, CaO, SiO_2, $2(CaO)SiO_2$, $2\frac{1}{2}(CaO)SiO_2$, $3(CaO)SiO_2$, and $4(CaO)SiO_2$. The lime was obtained by the ignition of pure precipitated calcium carbonate. The silica was prepared by conducting silicon tetrafluoride into water and then drying and igniting the gelatinous silicic acid thus formed. Intimate mixtures of lime and silica in the proportions to form the above compounds were heated by projecting vertically the flame of the oxy-coal gas blow-pipe down upon the mixtures in a cavity made in a fire brick. The heat thus obtained was sufficient to melt all except the last mixture, namely the $4(CaO)SiO_2$. The fused masses were in each case carefully separated from the unfused portions, they were chilled by sprinkling with cold water, dried and preserved in stoppered bottles. Weighed quantities were then hydrated by this method. The hydraulic properties of each compound were also examined by mixing some of the powdered compound with water and observing whether the mass set and became hard. The following table contains the results that were obtained: —

Compound.	Hydraulic properties.	Weight taken.	Wt. of Water taken up.	Per Cent of Water.	Per Cent of Lime.
$CaOSiO_2$	None.	.4829	.0004	.082	.26
$2(CaO)SiO_2$	Not quite as hard as cement	.3988	.0017	·43	1.33
"	"	.3997	.0012	.30	.93
$2\frac{1}{2}(CaO)SiO_2$	ditto	.4241	.0022	.52	1.61
$3(CaO)SiO_2$	Hard as cement	.4341	.0044	1.01	3.15
$4(CaO)SiO_2$	None	.4241	.0262	6.15	19.15

We conclude from these results that lime in combination with silica in quantities not exceeding three molecules of lime for one molecule of silica is only slowly acted upon by water and that this method of determining lime can be used to determine free lime in the presence of the basic di- and tricalcium silicates that are assumed to be present in Portland cements.

HYDRATION OF CALCIUM ALUMINATES.

The mono, di, and tricalcium aluminates were also prepared synthetically by fusing molecular quantities of pure alumina and lime with the oxy-coal gas blowpipe flame. The alumina was prepared by heating the hydroxide that had been obtained by precipitation from the chloride by ammonia. The aluminates all fused much more easily than the silicates under the oxy-coal gas blowpipe. Weighed quantities were hydrated by our method as in the case of the silicates and the hydraulic properties were also noted. It was found that the aluminates differ markedly from the silicates in their behavior towards water. This is shown by the following results: —

Compound.	Hydraulic properties.	Weight taken.	Wt. of Water taken up.	Per Cent of Water.	Per Cent of Lime.
$(CaO)Al_2O_3$	Set very hard,	.4886	.0652	13.34	41.52
$2(CaO)Al_2O_3$	like a cement	.4543	.0716	15.76	49.04
$3(CaO)Al_2O_3$	None.	.4072	.0796	19.55	60.80

We see from this that the aluminates are hydrated very much more rapidly than the silicates, in fact they behave like free lime when warmed with water to 85 degrees for 30 minutes. In the case of the monocalcium aluminate the percentage of water taken up shows a hydration of the alumina as well as of the lime. It is our intention to make a further study of this part of the subject. In determining free lime, therefore, by this method in substances containing calcium aluminates this fact must be borne in mind and the lime in combination with the alumina must be deducted from the total lime found.

BEHAVIOR OF CEMENTS.

As in commercial cements the proportion of alumina usually varies from 5 to 9 per cent we have prepared several cements by fusing with the oxy-coal gas blowpipe pure alumina, lime and silica in definite proportions and have then hydrated the resulting cements by our method. The following results were obtained: —

Composition of Cement.	Hydraulic properties.	Per Cent of Water taken up.
5 per cent Al_2O_3 25 " SiO_2 70 " CaO	Set slowly, did not become quite as hard as Portland cement.	1.43
9 " Al_3O_3 21 " SiO_2 70 " CaO	Set slowly and became quite as hard as Portland cement.	2.16
15 " Al_2O_3 15 " SiO_2 70 " CaO	Set slowly and became very hard.	4.65

We see from this that as the proportion of alumina increases the percentage of water taken up increases, but if the percentage of alumina does not exceed 10 per cent, as is the rule in commercial cements, then the amount of water taken up does not exceed 3 per cent.

A number of the best known varieties of commercial cements were then examined by our method. In each case the sample was weighed in a platinum crucible, then ignited for a few minutes over the blast lamp and after cooling in the desiccator it was weighed. The cement was then moistened with a few drops of water, the crucible put into the protector and warmed to 85 degrees for 30 minutes. Then the temperature was raised to 185 degrees and a slow current of air drawn through until constant weight was obtained. The following results were obtained: —

Cement.	Per Cent of Water taken up.	Cement.	Per Cent of Water taken up.
A,	1.16	I,	1.81
B,	1.97	J,	2.99
C,	2.09	K,	2.77
D,	2.67	L,	2.18
E,	2.88	M,	2.61
F,	2.66	N,	2.64
G,	3.01	O,	3.04
H,	3.10		

These cements all gave good "sound" tests and in nearly all cases less than 3 per cent of water was taken up. We conclude from this and from the preceding experiments upon cements that this water was taken up by the aluminates and that little or no free lime was contained in these cements. One variety of Portland cement that we examined gave 10.17 per cent of water taken up. We concluded that 7 per cent of this must be due to free lime being present. Our conclusion was justified, for on making a pat of the neat cement and allowing it to set thoroughly it was immersed in boiling water, and on removal from the water it showed signs of cracks and had become quite soft and readily disintegrated.

Two varieties of natural cements were tested and gave the following values: —

Natural Cement.	Per Cent of Water taken up.
A,	5.76
B,	3.70

Finally we have tested our method by adding weighed amounts of pure lime to a cement of known behavior and then after ignition with the blast lamp have again determined the percentage of water taken up. Thus cement A which took up 1.16 per cent of water had 15.40 per cent of lime added to it. Then on retesting it took up 6.25 per cent of water. Per cent of lime corresponding to 1.16 per cent of water equals 3.60. This plus the 15.40 per cent added equals 19.00 per cent. Lime corresponding to 6.25 per cent of water equals 19.44.

We conclude from our experiments that if a Portland cement containing less than 10 per cent of alumina takes up more than three per cent of water then this excess is due to the free lime present.

Issued December 4, 1903.

PUBLICATIONS.

The following publications of the Academy are offered for sale at the net prices indicated. Applications should be addressed to The Librarian, The Academy of Science of St. Louis, St. Louis, Mo.

TRANSACTIONS (in octavo).

Vol.	Number.	Price per number.	Price per vol.	Price in set.
1	1* 2† 3, 4	.... $4.00 2.00 each.	$7.50 (Nos. 2-4 only.)	$7.00 (Nos. 2-4 only.)
2	1 to 3	2.00 each.	5.50	5.00
3	1 to 4	2.00 each.	7.50	7.00
4	1 to 4	2.00 each.	7.50	7.00
5	1–2, 3–4	4.00 each. (double numbers)	7.50	7.00
6‡	1, 2, 6, 8, 10, 11, 16, 17 4, 5, 7, 13, 14, 15, 18 3, 9 12	25 cts. each. 50 cts. each. 75 cts. each. $1.00	7.50	7.00
7‡	2, 3, 4, 6, 7, 8, 13, 15, 16, 18, 19 5, 9 to 12, 14, 20 17 1	25 cts. each. 50 cts. each. 75 cts. $1.00	7.50	7.00
8‡	1, 3 to 6 8, 10, 12 2, 7, 9, 11	25 cts. each. 50 cts. each.	3.75	3.50
9‡	1, 3, 4, 7, 9 2, 5, 8 6	25 cts. each. 50 cts. each. $1.25	3.75	3.50
10‡	9 2, 4, 5, 10 1 3, 6, 7, 8, 11	10 cts. 25 cts. each. 40 cts. 50 cts. each.	3.75	3.50
11‡	2, 3 5–8, 10, 11 1 4 9	15 cts. each. 25 cts. each. 45 cts. 75 cts. 1.00	3.75	3.50
12‡	1, 9, 10 5 3, 8 2, 4, 6, 7	25 cts. each. 30 cts. 35 cts. each. 50 cts. each.	3.75	3.50

MEMOIRS (in quarto).

Contributions to the archaeology of Missouri, by the Archaeological Section. Part I. Pottery. 1880. $2.00.

The total eclipse of the sun, January 1, 1889. A report of the observations made by the Washington University Eclipse Party, at Norman, California. 1891. $2.00.

* Supply exhausted.

† Can be sold only to purchasers of the entire volume,— so far as this can be supplied.

‡ Each number is a brochure containing one complete paper (or rarely two).

Transactions of The Academy of Science of St. Louis.

VOL. XIII. No. 7.

A NEW GENUS OF GRASSES.

B. F. BUSH.

Issued December 11, 1903.

A NEW GENUS OF GRASSES.*

B. F. Bush.

While making a collection of plants along the sandy banks of the Brazos River, at Columbia, Brazoria County, Texas, on April 14, 1899, my attention was attracted by a robust matted, spreading form of *Eragrostis* very much like *Eragrostis hypnoides* (Lam.) B. S. P., but which was so different in the thicker stems which were pilose with short viscid hairs, the shorter, thicker short-pilose leaves, and the densely short-pilose sheaths, that I at once suspected I had found an undescribed species.

A careful examination of all the specimens of the creeping forms of *Eragrostis* seen at Columbia, Texas, during that day and the following days of my stay there, resulted in the discovery of another supposedly undescribed species of creeping *Eragrostis*, but did not disclose the presence of the real *Eragrostis hypnoides*.

I had provisionally named the two plants collected at Columbia, Texas, which were very different in appearance, the first having greatly elongated spikelets, and the other much shorter ones in a capitate cluster. While ransacking the synonymy of *Eragrostis* in the Kew Index at the library of the Missouri Botanical Garden to ascertain if the names I proposed to give these two plants were preoccupied in the genus *Eragrostis*, I was led to make an examination of *Poa* also, as many of the species of *Eragrostis* were first described under *Poa*, and there learned that there had been described a *Poa capitata* by Nuttall, in the Transactions of the American Philosophical Society, n. s. **5** : 146 (1837).

Being curious to learn what had become of this species described by so acute an observer as Nuttall, I consulted the

* Presented to The Academy of Science of St. Louis, November 2, 1903.

paper above-mentioned, and was very much surprised to learn that the two plants I had collected at Columbia, Texas, for two different species, had been described by Nuttall as *Poa capitata* from specimens collected by him in Arkansas about seventy years ago.

Nuttall characterizes his *Poa capitata* as being dioecious and viscid pilose, a fact which is all the more remarkable in that the makers of the Kew Index have referred Nuttall's species to *Eragrostis reptans* Nees, a disposition wholly unwarranted. A careful examination of my specimens revealed the fact that what I had collected and proposed to describe as two new species, were really staminate and pistillate plants of one and the same species, the first with the elongated spikelets, the staminate, the other with a capitate cluster of spikelets, the pistillate, a fact I have had abundant proof of in extensive field observations since learning of Nuttall's *Poa capitata*.

Nuttall's description of *Poa capitata* in the above-mentioned paper is as follows: —

> "Dioica, viscido-pubens; culmo reptante; panicula foeminea subrotunda lobata obtusa, mascula conferta; spiculis subduodecemfloris, lanceolatis; foliis distichis brevibus. — *Hab.* On the sand-beaches of the Arkansas. Flowering in July. . . . Annual and pilose . . . ; sheaths very short; stipules obsolete, pilose; female flowers spiked, the spikes subcapitate and lobed; male panicle acute, the spikelets less crowded, compressed, larger than those which are styliferous, and all 3-nerved, after the manner of this section, with which it arranges."

Nuttall evidently, in the above, refers to the flowering scales as being 3-nerved, and not to the spikelets, as worded in the description.

Since Nuttall's *Poa capitata* had been reduced to *Eragrostis reptans* in the Kew Index, and as very likely other related species had been treated likewise, I was desirous of seeing as much material of *Eragrostis reptans* as I could get, and also of consulting all the descriptions of species reduced to that species that were given in that work.

Amongst the many specimens examined in the herbarium of the Missouri Botanical Garden was one sheet of *Poa*

Weigeltiana Rchb., collected in Surinam by Weigelt in 1827, and described by Reichenbach in Mem. Acad. Sci. Peterbs. Ser. VI. **1**: 40 (1831), which is, at least in the Garden specimen, Nuttall's *Poa capitata*, and this name of Reichenbach's therefore antedates Nuttall's some six years. Nuttall was probably unaware of Reichenbach's species, or if aware of the publication, had not the least idea that his proposed species from Arkansas and the one from far away Surinam were one and the same. This Weigelt specimen (Pl. VII.) is represented by both male and female plants, and agrees perfectly with those collected by me at Columbia, Texas, and Fulton, Arkansas.

Reichenbach's label on the Weigelt specimen above mentioned, which is cut from the original publication, reads as follows: —

> "POA WEIGELTIANA Rchb. Eragrostis: repens cespitosa, vaginis ad oras ciliatis, paniculae (vix pollicaris) spiculis lineari-lanceolatis 15–20. floris glumisque (hyalinis viride-) trinerviis acutis. — Affinis *P. thalassinae* K. H. B. sed paniculata. Surinam. leg. et exsicc. Weigelt. 1827. determ. Rchb."

Nothing is said about the dioecious character, which the observant Nuttall detected, and it is likely that Reichenbach never suspected that the species was dioecious.

Much field observation during 1900, about Columbia, Texas, showed that this species of Nuttall's was very common there, and also resulted in the detection of the real *Eragrostis hypnoides*, which may now be said to be very rare along the Brazos River. Nuttall's species was also discovered on the sandy banks of the Red River at Fulton, Hempstead County, Arkansas, in the same year, accompanied by the real *Eragrostis hypnoides*, with which it formed quite a contrast. This last locality is not very far from where Nuttall collected his species on the Arkansas. During 1901 the study of the two plants was continued in the field, both at Columbia, Texas, and at Fulton, Arkansas, and the conviction was formed that these two related species are generically distinct from *Eragrostis*, not only by habit, but by the imperfect flowers. I therefore propose the following new genus: —

NEERAGROSTIS.

Prostrate, creeping and rooting, dioecious or monoecious grasses, with short flat leaves, and contracted paniculate inflorescence. Staminate and pistillate spikelets unlike; styliferous in subcapitate panicles, the spikelets closely flowered, the scales very acute, appressed; staminate in looser, elongated, acute panicles, usually larger and longer, the flowering scales longer and less acute, spreading. Spikelets many-flowered, more or less flattened; the two lower scales empty, unequal, shorter than the flowering scales, keeled, 1-nerved, or the second 3-nerved; flowering scales membranous, keeled, 3-nerved; palets shorter than the scales, prominently 2-nerved or 2-keeled, usually persisting on the rachilla after the fruiting scale has fallen; stamens 2 or 3; styles distinct, short; stigmas plumose; grain free, loosely inclosed in the scale and palet. — Two known species, both of the New World, much alike in habit, but differing considerably in character, both annual in North America, but probably perennial in tropical regions. Type species, *Poa Weigeltiana* Reichenb. Mem. Acad. Sci. Peterbs. Ser. vi. **1**: 40 (1831), collected in Surinam, — to which I have referred *Poa capitata* Nutt., of Arkansas.

Name composed of *Neo*, new, and *Eragrostis*, — New Eragrostis.

ANALYSIS OF SPECIES.

Dioecious. Flowering scales longer, pubescent: sheaths densely pilose pubescent. 1. N. WEIGELTIANA.

Monoecious. Flowering scales shorter, smooth; sheaths smooth or nearly so. 2. N. HYPNOIDES.

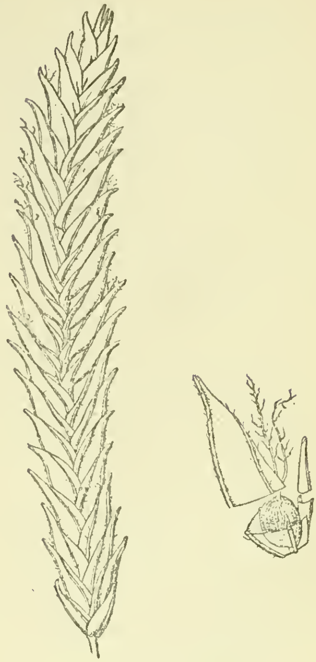
1. NEERAGROSTIS WEIGELTIANA (Reichenb.) B. F. Bush.

Poa Weigeltiana Reichenb. Mem. Acad. Sci. Petersb. VI. **1**: 40 (1831).

Poa capitata Nutt. Trans. Am. Phil. Soc. N. S. **5**: 146 (1837).

Eragrostis capitata (Nutt.) Nash in Britton, Man. Nor. States and Can. Append. 1042 (1901).

Culms prostrate and creeping, rooting at the nodes, sending up branches 5–15 cm. long; stems and especially the upper sheaths densely short-pilose; leaves short, flat, thick, spreading or ascending, 1–3 cm. long, 1.5–3 mm. wide, lanceolate, pubescent; panicle 2–3 cm. long, nearly or quite as broad, oval, subcapitate; spikelets crowded, clustered; pistillate spikelets longer and more narrow than the staminate, 2–4 cm. long, and 2–3 mm. wide, 25–100-flowered; lower scales unequal, awl-shaped, the lowest 1 mm. long, 1-nerved, the upper 1.5 mm. long, 3-nerved; flowering scales 3 mm. long, closely appressed, long-acuminate, the tips spreading in fruit, densely pubescent, 3-nerved; staminate spikelets shorter, wider, more spreading, 1–2 cm. long and 2–4 mm. wide, 15–40-flowered; lower scales unequal, awl-shaped, 1-nerved, the lower about 1 mm. long, the upper 1.5 mm. long; flowering scales 3 mm. long, spreading, acute, but tips less spreading, densely pubescent, strongly 3-nerved. — In wet, sandy soil along streams, Nebraska to Kansas, Arkansas, Texas, Louisiana, New Mexico, Mexico, Porto Rico, Central and South America. — *Plates VII, VIII.*



PISTILLATE SPIKELET.

STAMINATE SPIKELET.

Those who prefer *Eragrostis* to this genus may call this *Eragrostis Weigeltiana* (Reichenb.) Bush.

Specimens examined: —

Surinam: No locality, *Weigelt*, 1827.

Mexico: Matamoros, *Berlandier* 2325, date of collection not given, *Gregg* 911, June 6, 1847; Reynolds, *Gregg* 889, June 6, 1847; no locality, *Berlandier* 1949, date of collection not given.

Bolivia: Guanai, *Rusby* 230, May 1886.

Texas: Brazos Bottom, *Lindheimer* 213, 214, 111, August, 1843; no locality, *Berlandier* 895, date of collection not given; Aransas Bay, *Berlandier* 559, date of collection not given; no locality, *Wright* 2045, date of collection not given; Corpus Christi, *Heller* 1455, March 14–21, 1894; Columbia, Brazoria County, *Bush* 159, 159A, April 14, 1899; 265, October 26, 1899; 199, 199A, May 3, 1900; 1306, 1307, October 5, 1900; 1669, October 6, 1900; Graham, *Reverchon* 3500, October 29, 1902; Dallas, *Reverchon* 3499, October 24, 1902.

Arkansas: Fulton, Hempstead County, *Bush* 997, September 20, 1900; 1038, September 22, 1900.

Kansas: Chautauqua County, *Hitchcock* 932A, 1896, pistillate plant.

Nebraska: Lincoln, *Webber*, July 7, 1887, an unusually slender form with fewer spikelets in the clusters than in typical forms.

2. Neeragrostis hypnoides (Lam.) B. F. Bush.

Poa hypnoides Lam. Tabl. Encycl. **1**: 185 (1791).
Poa reptans Michx. Fl. Bor. Am. **1**: 69. *t. 11* (1803).
Eragrostis reptans (Michx.) Nees in Mart. Fl. Bras. **2**: 514 (1829).
Eragrostis hypnoides (Lam.) B. S. P. Prel. Cat. N. Y. 69 (1888).
Megastachya hypnoides Pal. de Beauvais, Essai d'une nouv. agrostographie 74 (1812).
Megastachya reptans Pal. de Bauvais, Essai d'une nouv. agrostographie 74 (1812).

Culms creeping and rooting, 3–5 cm. long, much branched, the branches erect or ascending, 3–15 cm. high; sheaths villous at the summit; leaves 2–5 cm. long, 1–2 mm. wide, flat, smooth beneath, rough above; spikelets dioecious, 10–40-flowered, 4–16 mm. long; lower scales unequal, the first one-half to two-thirds as long as the second; flowering scales about 2.5 mm. long, the lateral nerves prominent; scales of the pistillate flowers more acute than those of the staminate. — On sandy or gravelly shores, common throughout nearly all North America and in the American tropics.

Specimens examined: —

District of Columbia: Washington, *Steele*, 1896.

Connecticut: No locality, *D. C. Eaton*, 1859.

New York: No locality, Gray exsicc., date of collection not given.

Kentucky: No locality, *Short*, 1840; Hadley, *Sadie F. Price*, 1899; Harlan County, *Kearney* 55, 1893.

Ohio: Milan, *Moseley*, 1894; Cincinnati, *Lloyd*, 1884.

Iowa: Ames, *Hitchcock*, 1888; Clinton, *Pammel* 239, 1896; Boone County, *Pammel and Ball* 108, 1896; Des Moines, *Ball* 1379, 1898; Turin, *Pammel* 1032, 1894.

Wisconsin: LaCrosse, *Pammel*, 1887; LaCrosse River, *Hall*, 1861.

Nebraska, Wabash, *Williams*, 1889; Lincoln, *Webber*, 1877; Fort Pierre, *Hayden*, 1853.

North Carolina: Wilmington, *McCarthy*, 1885; Lincoln County, *Curtis*, 1847.

Louisiana: Baton Rouge, *Joor*, 1885; New Orleans, *Hale* 1603, 1605, date of collection not given; Alden Bridge, *Trelease*, 1898; Jackson, Buckley Herbarium, without date; Comite Swamp, *Joor*, 1885.

Arkansas: Fulton, *Bush* 963, 1900; no locality, *Beyrich*, 145, 1834.

Tennessee: Columbia, *Shimek*, 1891.

Indian Territory: Sapulpa, *Bush* 825, 1894.

Missouri: Jefferson Barracks, *Pammel*, 1886; Courtney, *Bush* 591, 1896; Kennett, *Bush*, 1893; Jackson County, *Bush*, 1891; Campbell, *Bush* 810, 1894; Swan, *Bush* 602, 1899; St. Louis, *Engelmann* 108, 1838.

Kansas: Riley County, *J. B. Norton* 932, 1896; *Kellerman*, 1888; Manhattan, *J. B. S. Norton*, 1892; Sedgwick, Sumner and Cherokee Counties, *Clothier and Whitford*, 1897; Douglas and Labette Counties, *Hitchcock*, 1899; Atchison County, *Hitchcock*, 1896; Jewell and Republic Counties, *J. B. S. Norton*, 1895; Johnson County, *H. S. Pellet*, 1890; Topeka, *E. A. Popenoe*, 1876; Bourbon County, *Hitchcock*, 1892; Wyandotte County, *Mackenzie*, 1896.

Texas: No locality, *Joor*, date of collection not given; Texarkana, *Heller*, 1898; no locality, *Lindheimer* 214, 1843; Columbia, *Bush* 1304, 1900; Mineola, *Reverchon* 2815, June 9, 1902; Rusk County, *Vinzent*, date of collection not given.

Oregon: Multnomah County, *Howell* 430, 431, 1877; no locality, *Hall* 631, 1871.

Florida: No locality, *Chapman*, date of collection not given.

California: Sacramento, Thurber Herbarium, an unusually pubescent form otherwise typical.

Illinois: Belleville, *Engelmann* 108, 1833; Cahokia, *Engelmann*, 1859.

Michigan: Kalamazoo, 1838, in Thurber Herbarium, collector not noted.

Mexico: Papantla, *Liebmann* 537, 1841.

Nicaragua: No locality, *Wright*, 1853–6.

Brazil: Para, *Duplum*, date of collection not given; Amazon River, *Spruce*, date of collection not given; Bahia, Bernhardi Herbarium, without date or collector.

Cuba: Bernhardi Herbarium, 1824, without locality or collector.

Porto Rico: Cabo-Rojo, *Sintenis* 674, January 23, 1885.

San Domingo: Bernhardi Herbarium, without other data.

EXPLANATION OF ILLUSTRATIONS.

Plates VII–VIII.

Plate VII.— *Neeragrostis Weigeltiana.* Sheet of Weigelt's Surinam collection of 1827, in the Bernhardi Herbarium of the Missouri Botanical Garden. Reduced.

Plate VIII. — *Neeragrostis Weigeltiana.* Texas, Bush, 1900. The upper figure (No. 1306), represents typical pistillate inflorescence: the lower (No. 1307), typical staminate inflorescence. Natural size.

Issued December 11, 1903.

NEERAGROSTIS WEIGELTIANA.

PISTILLATE.

STAMINATE.

NEERAGROSTIS WEIGELTIANA.

PUBLICATIONS.

The following publications of the Academy are offered for sale at the net prices indicated. Applications should be addressed to The Librarian, The Academy of Science of St. Louis, St. Louis, Mo.

TRANSACTIONS (in octavo).

Vol.	Number.	Price per number.	Price per vol.	Price in set.
1	1* 2† 3, 4	.... $4.00 2.00 each.	$7.50 (Nos. 2-4 only.)	$7.00 (Nos. 2-4 only.)
2	1 to 3	2.00 each.	5.50	5.00
3	1 to 4	2.00 each.	7.50	7.00
4	1 to 4	2.00 each.	7.50	7.00
5	1-2, 3-4	4.00 each. (double numbers)	7.50	7.00
6‡	1, 2, 6, 8, 10, 11, 16, 17 4, 5, 7, 13, 14, 15, 18 3, 9 12	25 cts. each. 50 cts. each. 75 cts. each. $1.00	7.50	7.00
7‡	2, 3, 4, 6, 7, 8, 13, 15, 16, 18, 19 5, 9 to 12, 14, 20 17 1	25 cts. each. 50 cts. each. 75 cts. $1.00	7.50	7.00
8‡	1, 3 to 6 8, 10, 12 2, 7, 9, 11	25 cts. each. 50 cts. each.	3.75	3.50
9‡	1, 3, 4, 7, 9 2, 5, 8 6	25 cts. each. 50 cts. each. $1.25	3.75	3.50
10‡	9 2, 4, 5, 10 1 3, 6, 7, 8, 11	10 cts. 25 cts. each. 40 cts. 50 cts. each.	3.75	3.50
11‡	2, 3 5-8, 10, 11 1 4 9	15 cts. each. 25 cts. each. 45 cts. 75 cts. 1.00	3.75	3.50
12‡	1, 9, 10 5 3, 8 2, 4, 6, 7	25 cts. each. 30 cts. 35 cts. each. 50 cts. each.	3.75	3.50

MEMOIRS (in quarto).

Contributions to the archaeology of Missouri, by the Archaeological Section. Part I. Pottery. 1880. $2.00.

The total eclipse of the sun, January 1, 1889. A report of the observations made by the Washington University Eclipse Party, at Norman, California. 1891. $2.00.

---

* Supply exhausted.

† Can be sold only to purchasers of the entire volume,— so far as this can be supplied.

‡ Each number is a brochure containing one complete paper (or rarely two).

Transactions of The Academy of Science of St. Louis.

VOL. XIII. No. 8.

POLYGAMY AND CERTAIN FLORAL ABNORMALITIES IN SOLANUM.

THE GERMINATION OF PACHIRA, WITH A NOTE ON THE NAMES OF TWO SPECIES.

J. ARTHUR HARRIS.

Issued December 12, 1903.

POLYGAMY AND CERTAIN FLORAL ABNORMALITIES IN SOLANUM.*

J. Arthur Harris.

The genus *Solanum* is generally characterized as hermaphrodite. No indication to the contrary is given in Gray's *Manual*, Britton and Brown's *Illustrated Flora*, Britton's *Manual*, Chapman's *Flora of the Southern United States*, Bentham's *Flora Australiensis*, Hooker's *Flora of British India*, or Trimen's *Handbook of the Flora of Ceylon*. No indication of any but perfect flowers is given in the treatment of the genus in Bentham and Hooker's *Genera Plantarum*, or Engler and Prantl's *Natürliche Pflanzenfamilien*.

While the presence of polygamy is infrequently noted in characterizing the genus in general systematic works, it has by no means remained unnoticed, for the abortion of the pistil has been recorded in the description of many species, and, indeed, has been several times considered in the description of the genus. Dunal, in 1813 (*Histoire des Solanum*), mentions sterile flowers in his characterization of the genus and in another place in the same work enters into a quite detailed discussion of the phenomenon, stating that a large number of Solanums have fertile and sterile flowers which are usually smaller and owe their sterility to the failure of the pistil to develop, it being shorter than the stamens, usually of about the length of the filaments, and so not in a position to receive the pollen, while in the fertile flowers the pistil is at least as long as the stamens so that the stigma is placed in the most favorable position to secure the pollen. Furthermore, he says, in some species provided with prickles the calyx of the fertile flowers is provided with these appendages while the sterile ones are without them; thus in the

* Presented to The Academy of Science of St. Louis, November 2, 1903.

section *Melongena* where the inflorescence is divided into two branches, one being shorter, stouter and bearing but a single flower which has a calyx armed with prickles, the other bearing several flowers which are smaller and bear but few or no prickles on the calyx, the large flower is fertile while the others are usually sterile.

In a recent paper Heckel,* after quoting the statement to which reference has just been made, states that while he cannot speak for all the species of Dunal's section *Melongena*, in *S. Duchartrei* as in *S. esculentum* there exists a real monoecious unisexual condition realized by the complete abortion of the pollen in the stamens of the female flower in the egg plant, while in *S. Duchartrei* the stamens of the female flower contained pollen of a much smaller dimension than that of the male flower which is very well developed. Furthermore the physiologically male flower had a small stigma covered with short dry papillae, while in the female flower the stigma was very capitate, green, and covered with long moist papillae. The ovules seemed to have the same development in both cases.

It is of interest to notice that Dunal, in *Histoire des Solanum* says: † "Dans le *Sol. longifolium* j'ai vu le style simple d'abord, se diviser en trois vers la fin de la floraison." Heckel says of *S. Duchartrei*: "L'ovaire, le style et le stigmate sont très réduits en dimensions dans la fleur mâle: la stigmate est quadrifide, dans la fleur mâle et capité dans la fleur femelle." In his laborious monograph of the genus in De Candolle's *Prodromus* Dunal says: "Flores hermaphroditi, rarius polygami, saepe pistillo abortivo steriles." Sendtner, in his treatment of the Brazilian forms in the tenth volume of Martius' *Flora Brasiliensis*, says: "Flores hermaphroditi, rarius polygami, saepe gynaeceo abortivo steriles. * * * Pistillum in plerisque speciebus in ejusdem plantae diversis floribus, nunc completum, nunc incompletum occurrit. * * * Stylus terminalis, longus

* Heckel, E. Une Nouvelle Espèce de l'Afrique Tropicale. *Solanum Duchartrei.* Rev. Gén. Bot. **2**: 49–54. 1890.

† Page 92.

(vel in abortivis decurtatus)." Gray, in the *Synoptical Flora*, says: "Sometimes polygamous, through the abortion of the pistil of many of the flowers."

Dunal, in De Candolle's *Prodromus*, recognizes, in his *Conspectus Generis Solani*, two sections, *Pachystemonum* and *Leptostemonum*, which he further divides quite extensively. One of these ultimate divisions, *Polygama*, of the subsection *Euleptostemonum* of his second section *Leptostemonum*, he devotes to those species with "floribus polygamis, calycibus florum femineorum post anthesin auctis," and includes in it his numbers 477–479. Of *Mogenoplum* of the third subsection, *Asterotrichotum*, of *Leptostemonum*, he says: "Floribus pluribus abortivis. In flore fertile, stylus antheris longior; in floribus sterilibus, stylus filamentorum longitudine," and of *Melongena* of the same subsection he says: "Pedunculis * * * interdum solitariis unifloris, saepius inferne bifidis; pedicello infero, e caule nascente, florem unicum fertilem gerente, post anthesin cernuo; pedunculi altera parte multiflora, flores steriles gerente. In flore fertile, calyx post anthesin crescens, aculeatus in speciebus aculeatis; stylus antheris longior. In flore sterile, calyx inermis, aut vix aculeatus in spec. aculeatis; stylus longitudine filamentorum." In Dunal's arrangement *Mogenoplum* includes numbers 773–802, while the following section, *Melongena*, includes 803–851. Thus from his synopsis of species, 82 of his 898 species would be characterized as polygamous.

Sendtner in *Flora Brasiliensis*, uses a somewhat different method of division, employing three main sections, and nowhere giving any division to those with polygamous inflorescence. Wettstein in *Die Naturlichen Pflanzenfamilien* recognizes five sections. Dunal has been criticised by systematists for his treatment of the genus, and it certainly seems not improbable that the arrangement may ultimately be different from any so far proposed.

Darwin publishes* a letter from Fritz Mueller to himself in which some South American species of Solanum with long-

---

* Nature **17**: 78–79. 1877–1878.

and short-styled flowers are mentioned and characterizes the short-styled forms as male in function since as they are visited exclusively by pollen-collecting bees there is no way in which pollen can be transferred to the stigma. In commenting on the letter Darwin correctly interprets them as cases of polygamy through abortion rather than truly heterostyled forms.

Early in the summer of 1902, I noticed that there occurred in many of the flowers of *S. Carolinense* L. a strong reduction in the size of the pistil, and concluded that some idea of the frequency of the occurrence might be of interest from a biological, and possibly from a taxonomic, standpoint.

While all the literature of *S. Carolinense* has not been examined the most important has been consulted. The only reference to the sterile flowers seems to be that of Sendtner, who says of this species: "Flores vidi nonnisi steriles absque pistillo." The pistil shows considerable range in form, being sometimes exserted for perhaps as much as two-thirds the length of the anthers, while again the capitate green stigma extends only to the end of the anthers, or a less distance. Dunal, in the *Prodromus*, says: "Stylus * * * rectus et staminibus longior vel apice recurvatus et staminibus brevior," which appears to be due to lack of material, for in a very large per cent. of the exserted styles examined there is a more or less strong curvature, while in those of the length of the stamens or less, it is either straight or curved. In the sterile form the pistil is simply reduced in size, having about the same length as the filaments. Sometimes the stigma has assumed the characteristic green coloration, and sometimes not. The form of the pistil in the mature sterile flower corresponds to that of the pistil in the young bud of the perfect flower. The development of the stamens is at first more rapid than that of the pistil.

While I have not now before me such a series of material, I feel confident that in the material examined there was a complete series of mature flowers extending from the longest-styled forms to those in which the pistil is most reduced. At the same time, transition stages are rare, the reduction, where it occurs, being usually very pronounced.

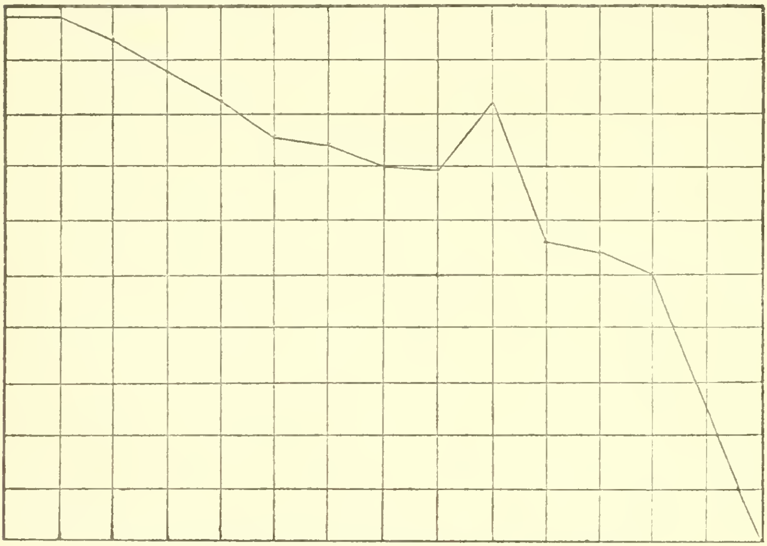
As to the relative number of perfect and sterile flowers occurring at one time, the following list shows the condition of flowers selected at random on the grounds of the Missouri Botanical Garden and on vacant lots within a radius of two or three miles of the Garden: —

Date.	Perfect.	Staminate.
July 20	66	16
July 28	98	22
July 29	10	0
July 31	409	61
August 2	145	43
August 3	70	29
August 5	65	14
July 20–August 5, 1902,	863	185

This gives 82.2 per cent. of perfect flowers and 17.6 per cent. of those with undeveloped pistils. At Lawrence, Kansas, in July, up to the 7th, of 205 flowers examined, 166 were perfect and 39 sterile. In 182 flowers examined at Thayer, Kansas, August 5, 177 were perfect and 5 sterile. While few tabulated countings were made, practically the same conditions were found in material examined during the summer of 1903.

The lower flowers of a cluster are almost always perfect, while those near the end are much more likely to be simply staminate. The reduction in the pistil may occur in any or all of the flowers of the inflorescence. To gain some idea of the relative position of the sterile flowers, 100 clusters were selected as nearly at random as possible, the only limitation, and that a rather large one, being the necessity of selecting such material as had lost none of its individual flowers and was yet of such maturity that the sexual condition of the terminal buds might be determined with certainty. The flowers were numbered from the base to the tip of the main axis, which produced, in the material examined, from two to fifteen flowers, with an average of eight. The inflorescence of *S. Carolinense* is quite variable, and, while for the list of 1048 the flowers were selected perfectly at random, for the following table the material was necessarily confined to the simple racemose type of inflorescence.

The results have been expressed in the accompanying frequency curve in which the fifteen vertical lines represent the relative position of the flowers on the central axis, while the percentage of perfect flowers present in that number is shown on these lines by the percentage curve. Beginning with 98 per cent. of the flowers perfect in the first two flowers in the one



Pistil reduction in Solanum Carolinense.

hundred clusters examined, it runs down to zero in the fifteenth, both of the terminal flowers in the two cases in which fifteen were produced being sterile. In the fourteenth place, there are present three staminate and one perfect flower, 25 per cent., and in the thirteenth, three staminate and three perfect, 50 per cent. Cases are frequent enough in which all of the flowers are perfect, even where as many as fifteen are produced, so that the table does not necessarily represent the average condition. It does, however, show the condition of one hundred individuals, selected as nearly as possible without personal bias, and represents something near the average condition.

The proportion of the two types is by no means the same for different localities, in some spots the perfect flowers being present in the average proportion, or even almost exclusively, while at a short distance will be found an unusually high percentage of sterile flowers. On four plants growing quite near together were noted August second: —

Plant I	1 perfect	1 staminate.
Plant II	2 perfect	2 staminate.
Plant III	4 perfect	4 staminate.
Plant IV	4 perfect	23 staminate.

Other groups of plants were noticed which would have given similar results as well as those which would have given almost exclusively perfect flowers. The same condition was observed during the summer of 1903 in an even more striking degree. Whether the fact that these plants grew close together has any significance or not was not determined. The nature of the subterranean system of *S. Carolinense* will be borne in mind in this connection.

In most of the descriptions of *S. sisymbrifolium* Lam. the reduction of the pistil is not mentioned, the only reference noticed being that in the *Botanical Magazine*, where, in the description of *Plate 2568*, there is the parenthetical remark: "Baron Jacquin remarks that in the sterile flowers the calyx is hairy, and in the perfect flowers, prickly." Dunal does not refer to it in his monograph.

In the Missouri Botanical Garden I have been able to watch a considerable number of thrifty plants of this species during two years. The pistils of the more terminal flowers are reduced in a manner very similar to that of *S. Carolinense* but more frequently, a plotted curve showing a much more rapid fall than in the species particularly studied, there being on some of the racemes only three or four of the lower flowers perfect.

These instances suggest that an examination of living material may show many more species of the genus to be polygamous. The large percentage of sterile flowers, caused by cessation of development of the pistil, might indicate that the failure of the pistil of the more terminal flowers to develop is due to defective nutrition. It seems highly probable that the condition is not a pollination adaptation, that is one evolved primarily to secure a division of labor in the flowers. The flowers of both species are rather conspicuous, those of *S. sisymbrifolium* especially so, without nectar, as is characteristic of the genus, and without odor in *S. Carolinense* but with a very pronounced odor closely resembling that of *S. rostratum* in *S. sisymbrifolium*. The only published observations on the pollination of *S. Carolinense* of which I am aware are those of Robertson* who describes the flowers as adapted to Humble Bee females which visit them for pollen. He saw *B. Americanorum* F. collecting pollen. The flowers of this species are very rarely visited by insects. During the three summers I have been particularly interested in Solanum pollination I have only once seen Bombus collecting pollen but much of the time my opportunities for field work were not the best. My sister informs me that at Lawrence, Kansas, during the summer of 1903 the flowers were not much visited but that especially in the early morning one could usually find at least one Humble Bee working on the flowers. The very noticeable perfume of *S. sisymbrifolium* suggests more frequent insect visits. During the summer of 1902 when only one bed of this species was grown at the Garden no insect visits were observed, though fruit was borne freely, but in 1903 when the collection was much more extensive large bees were observed collecting pollen with the greatest frequency. In his paper on Brazilian Solitary Bees Schrottky gives† *S. Balbisii* Dun (=*S. sisymbrifolium*), as one of the principal flowers visited by Xylocopa.

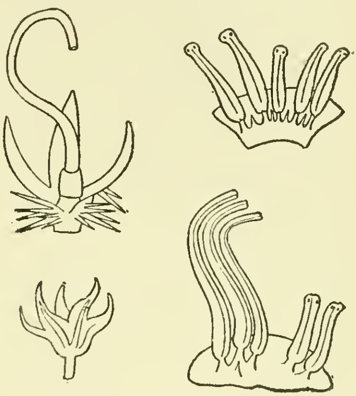
It is certainly of interest to note that in at least one species of the genus, *S. Amazonium*, the pistil is not the only organ markedly affected. The species was first described

---

* Robertson, C. Flowers and Insects. This journal 5: 582. 1892.

† Schrottky, C. Ensaio sobre as Abelhas Solitarias do Brazil. (Revista do Museu Paulista. 5: 458). 1902.

and figured in *The Botanical Register*,* the parts of the description concerning us in the present connection being: "Flos primarius cujusque racemi solus hermaphroditus, caeteri masculi. Cal. * * * in hermaph. cum pedicello echinatus, (fructu simul excrescens?): in mare inermis atque cadens cum corolla. * * * Anth. flavae, subsessiles contiguae, declinatae; in maribus inaequalissimae, 3 imis maximis corniformibus arcuatis parallelis corolla paulo brevioribus: in hermaph. parum inaequales, * * *. Flos masculus nondum expansus refert papilionaceum non apertum." "The corolla of both flowers is irregular, but that of the barren one more conspicuously so, the angles or segments being separated by a much deeper sinus than in the fertile one."



Floral details of Solanum Amazonium. — Edwards.

In Curtis's *Botanical Magazine* † the species is described as *Nycterium Amazonium.* "The upper flowers in the corymb are generally male, and, consequently, sterile, the lowermost hermaphrodite and fertile; of the latter, only the calyx is covered with straight, sharp prickles, that of the male is altogether unarmed. * * * Anthers unequal, declined: in the male flowers generally three long and two short, in the hermaphrodite two long and three short, or frequently all nearly equal. * * * In the male flowers, style and stigma defective."

Loddiges ‡ mentions the thorny calyx of the "fruitful flowers, which are usually the lowest." Nees ab Esenbeck, § does not mention the polygamous inflorescence of this species.

---

* Edwards. The Botanical Register, **I.** *Pl. 71.* 1815.

† **42.** *Pl. 1801.* 1815.

‡ Loddiges and Sons. The Botanical Cabinet. 4. no. 352. London. 1819.

§ Nees ab Esenbeck. Horae Physicae Berolinenses. 1820. p. 51. *pl. 9.*

The description by Dunal in the *Prodromus* is similar to that in the *Botanical Register*. Rose * says: "In the sterile flowers the calyx is naked and the lower anthers much longer (6 lines long); in the fertile and lower flowers the calyx is armed with prickles and the anthers nearly even or often longer."

The only reference to the pollination of this plant known to the writer is that of Delpino † who places in it his Seventh Class under "Tipo Melastomaceo." "*Solanum Amazonicum* ‡ antere biporose all'apice. Stami superiori sterili, abbreviati e metamorfizzati in fulcri."

In *S. Amazonium*, then, the structure of the calyx, corolla and stamens has undergone a strong modification in the two types of flowers. From what we know of the pollination of *S. rostratum* and of certain species in other families there can be no reasonable doubt that *S. Amazonium* is pollinated by insects. In this case, then, it may be that certain of the secondary modifications in the polygamous flowers of this species are real modifications for the securing of pollination, but for a clear understanding of the structures direct ecological observations are desirable.

In the section *Melongena* there are found, according to Dunal and Heckel, modifications in the inflorescence, in the calyx and even in the stamens of the staminate and pistillate flowers. In *S. sisymbrifolium* a difference in the armature of the calyx of the hermaphrodite and staminate flowers has been recorded but it is not nearly so conspicuous in living material as in *S. pyracanthum* where the difference is very marked. In many other armed species the same difference will doubtless be found.

According to Heckel there exists in the flowers of some species of the section *Melongena* a real unisexual condition so that the plants are monoecious. In his key Dunal divides his section *Polygamia* into monoecious and dioecious forms.

---

* Rose, J. N. List of Plants Collected by Dr. Edward Palmer in Western Mexico and Arizona in 1890. (Cont. U. S. Nat. Herb. **1**: 91–127. 1891.)

† Delpino, Federico. Ulteriori Osservazioni. Parte II. fasc. II. Milano. 1875. Estratto dagle Atti. Soc. Ital. Sci. Nat. in Milano, 1873–1874.

‡ Evidently a typographical error, the name being *S. Amazonium.*

The occurrence of some plants of *S. Carolinense* with an unusually high percentage of staminate flowers has already been pointed out. On several plants of *S. robustum* grown at the Garden only staminate flowers were produced. No insect visits were noticed but while not very large or highly colored the flowers were visible for some distance and the *rostratum*-like odor was quite strong.

In *S. Carolinense* synanthy was observed quite frequently and in almost all stages. Four- and six-merous flowers were abundant. Synanthy has been recorded as common for some other species of the genus and 4- and 6-merous flowers seem to occur normally in some species. In one case a partially petaloid stamen, also a not uncommon occurrence in the genus, was seen.

In *S. sisymbrifolium* one corolla divided to the base and having on the free edges anther-like structures, more perfect in one case but pollen-bearing in both, was found. According to Penzig staminody of the petals has been quite frequently noted in *S. tuberosum*.

In the genus *Solanum* the section *Nycterium* as defined by Wettstein in Engler and Prantl's *Naturliche Pflanzenfamilien* contains fourteen species showing a markedly zygomorphic structure. The stamens are the organs primarily affected, either the lower or the three lower showing a much larger and longer anther which is usually strongly curved upward at the tip. The corolla is in some species regular and in some irregular, the two lower lobes being somewhat produced so as to envelop in the bud the longer, lower, stamen or stamens and pistil.

The occurrence of a dimorphism in the stamens of *Solanum* as a teratological phenomenon is not unknown. Todd* says: "The obliquity of the stamens, or their vertical asymmetry as it might be called, appears in *S. tuberosum* sometimes. I have observed it in the 'peach-blow' variety; I have observed it more frequently in *S. Carolinense*."

Penzig† says for *S. cornutum* Lam.: "Moquin-Tandon

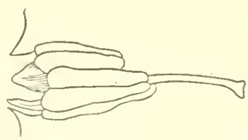
---

* Todd, J. E. On the Flowers of *Solanum rostratum* and *Cassia chamaecrista*. (Amer. Nat. **16**: 281–87. 1882.)

† Penzig, O. Pflanzen Teratologie **2**: 171.

giebt an ein Stamen weit länger als die übrigen gesehen zu haben (ähnliche Längendifferenz ist in andern Arten normal)." I have examined Moquin-Tandon's* statement and find that it is: "J'ai découvert, près de Toulouse, un individu de *Solanum Dulcamara*, dans lequel toutes les fleurs supérieurs offraient tantot deux, tantot trois étamines beaucoup plus longues et plus grosses que les autres." In a foot-note he then gives *S. tridynamum* (Poir) and *S. Amazonium* (Bellend) as producing three elongated stamens and *S. vespertilio* (H. Kew) and *S. cornutum* (Juss.) as those in which "une étamine seulement acquiert une taille double du volume habituel."

The citing as an abnormality of the production of one stamen longer than the others in *S. cornutum* Lam. is evidently an error due to an oversight on the part of Dr. Penzig. The "*S. cornutum* (Juss.)" to which Moquin-Tandon refers is apparently the *S. cornutum* described by Juss.,† which is *S. cornutum* Lam. *S. cornutum* Lam. is clearly one of the species with produced stamens, according to the description given by Dunal in his monograph, and the original description of Lamarck.‡ *S. cornutum* (Hort. Monsp.) according to Dunal § equals *S. rostratum* Dun. Under *S. Dulcamara* L. Penzig says: "Im Androeceum beobachtet man bisweilen, dass zwei oder drei Stamina länger sind als die übrigen," but does not refer to the literature, so that the observation may be one of his own.



SOLANUM TUBEROSUM.—Todd.

In one flower of several taken from a plant of *S. nigrum* near St. Louis. Mo., one of the stamens was noticeably longer than the others, the increased length being partly in the filament and partly in the anther.

---

* Moquin-Tandon, A. Éléments de Tératologie Végétale. Paris. 1841, p. 138.

† Juss. in Ann. Mus. Hist. Nat. **3**: 120. *t. 9*, as cited by Pursh, Flora Americae Septentrionalis. Second Ed., London, 1816, and Dunal in De Candolle, Prodromus Regni Vegetabili. **13**[1]. 1852.

‡ Lamarck, Tableau Encycloped. Methodique. Botanique. **2**: 25.

§ Dunal. l. c.

The figure given by Todd of the abnormal *S. tuberosum* shows a marked difference in the anthers. He does not figure the occurrence he describes in *S. Carolinense*, and I have never been so fortunate as to discover such an example in many hundreds of flowers examined. Of all these, the anthers have been so nearly equal that the difference, if present, was not readily detected with the naked eye. In a large percentage of the flowers, however, the lower stamens do project a little beyond the upper, owing to the oblique rather than vertical position of the whole androecium. In *S. sisymbrifolium*, where the filaments and anthers are longer, the stamens are a little more declined from the exact longitudinal axis of the flower. The same is true of *S. tuberosum* and has already been recorded by Mueller, who says in *The Fertilisation of Flowers:* "All the stamens bend very slightly downward, and the lower anthers project somewhat in advance of the others." It seems not improbable that the normal projection of the lower stamens in *S. Carolinense* was mistaken by Todd for a real structural difference.

In this place some of the taxonomic literature on *S. heterodoxum* Dunal is of interest. This species was first described by Dunal* who placed it with *S. cornutum* Lam. and *S. rostratum* Dun. in a section devoted to species with unequal anthers, giving as the description of the anthers for this species: "Stamina 5, antherae 4 luteae, interdum nunc inde nigrescens subrectae, 5 decumbens, productissima, apice corniculata, saepius nigricans, stylus rectus. Stigma bilobum." In his monograph he regards it as one of his species, but in his *Histoire des Solanum* he cites "*S. heterodoxum* De Cand. Hort. Monsp. Mss. Tabula picta" and gives as habitat "in Horto Monspeliense cultum" where he saw living material. His figures on Pl. 25 represent the flowers as small, scarcely half an inch in diameter, hardly zygomorphic, the stamens not very unequal. In his *Synopsis* † Dunal says: "Corollis subregularibus, antheris parvis declinatis, infima longiori

* Dunal. Histoire des Solanum. 1813.

† Dunal, M. F. Solanorum Generumque affinium Synopsis. Montpellier. 1816. p. 46.

apice curvata subfusca," and gives as habitat "In Mexico. Humb. et Bonpl. (v. v. h. M.) Cor. coerulea." Kunth * cites Dunal in the Synopsis. In his description the lobes of the corolla are given as equal, anthers as "unequal (?)," and stigma subcapitate. *S. citrullifolium* A. Br. (= *S. heterodoxum* Dun.) is described † as follows: "Corolla ampla (*Solani tuberosi* corollam aequante), irregulari, coeruleo-violacea; antheris declinatis, infima reliquis duplo longiore productissima curvata. — Semina Texana *Lindheimeriana* sub nomine *Nycterii violacei* communicavit Engelmann." Regel ‡ describes *S. citrullifolium*. Both his descriptions and the figures, pl. 112 (?), represent the lower, fifth, stamen as about twice the length of the others. In his monograph in De Candolle's *Prodromus* Dunal does not cite *S. citrullifolium*, but in the *Addenda et Corrigenda* at the end of the work Alphonse De Candolle gives the description of this species and regards it as an insufficiently known species belonging with their species 759–766.§ *S. heterodoxum* is described in detail: "Antherae * * * 4 subaequales, 2 lin. longae * * * quinta valide declinata, paulo longior, 2–2⅓ lin. longa, superne arcuata," the citation of material being: "v. v. et s. in h. DC., H.B. et Kth., Requien, Boiss." Torrey ‖ catalogues *S. citrullifolium* A. Braun from Plains near Puerto de Paysano and near the Limpio: July–September. "Flowers large, violet, an inch in diameter. The last three species ¶ belong to a remarkable group (Cryptocarpum, *Dunal*) which Nuttal regarded as a proper genus (Androcera)." As the next species he gives "*Solanum heterodoxum Dunal*, l. c. [in Prod.] p. 331? On the Rio Grande, below Presidio del

---

* Kunth, C. S. Nov. Gen. et Sp. Pl. **3**: 46. 1818.

† Ann. Sci. Nat. III. **12**: 356. 1849.

‡ Regel, *Solanum citrullifolium* R. Br. Regel's Gartenflora. **4**: 78–9. 1855.

§ These species are *S. tribulosum* Schau., *S. cornutum* Lam., *S. rostratum* Dun., *S. Fontanesianum* Dun., *S. chrysacanthum* Dun., *S. propinquum* Mart., *S. Bejarense* Dun. and *S. heterodoxum* Dun.

‖ Torrey, John. Botany of the Boundary. p. 152. 1859.

¶ He evidently means this, the preceding, and the following species, rather than this and the two preceding or the last three species of the list, since the latter arrangements which are the literal interpretation of his statement, would include *S. elaeagnifolium* Cav. or *S. verbascifolium*.

Norte; August; *Parry*. Corallitos, Chihuahua; *Thurber*. Differs from the last in the excessively hispid stem and branches, and in the much smaller flowers.'' In Gray's *Synoptical Flora* the reference to *Histoire des Solanum* as the place of first publication of this species is followed by the parenthetical expression: ''Small-flowered form cult. at Montpelier.''

I have seen none of the original material upon which *S. heterodoxum* Dun. is based, but have seen in the Engelmann Herbarium at the Missouri Botanical Garden, a good series of *S. citrullifolium* A. Braun (some collected by Lindheimer and one sheet with Braun's name). In all of this material the structure of the flower is very similar to *S. rostratum* Dun. The difference in the anther of the lower stamen and the upper four is very pronounced and the stigma is not at all capitate, while in the living material which I have seen the differences in the size of large and small stamens is even more pronounced than in *S. rostratum*. The species is interesting in this connection since there is a strong indication of two forms of androecium in *S. heterodoxum* Dun., the one in which the difference in the anthers is very pronounced and the other in which there is very little difference. Of course there is a possibility that *S. heterodoxum* Dun. represents two distinct species, in which case *S. heterodoxum* will be retained for the small-flowered form with nearly equal anthers and capitate or subcapitate stigma, while *S. citrullifolium* A. Br. will be applied to the forms with the large strongly zygomorphic flowers.

The appearance of a dimorphism in the stamens of a normally regular androecium has been noted in more than one case, but this is the only instance which has so far come to my notice in which a reduction to an almost regular form of a pronounced Nycterium type like *S. heterodoxum* Dun. might be suspected.

The division of this vast genus of about 900 species is very unsatisfactory. Wettstein in *Die Naturlichen Pflanzenfamilien* has more than any other writer used the characters offered by the stamens. The characters of his sections so far as they concern us in this place are as follows: —

I. Pachystemonum. All stamens equal in length or nearly equal. About 400 species.

II. Lycianthes. Filaments of unequal length, one exceeding the other. About 80 species.

III. Leptostemonum. Filaments of equal length. About 400 species.

IV. Lycopersicum. All stamens equal. About 10 species.

V. Nycterium. Flowers zygomorphic, either with unequal stamens only or with zygomorphic corolla in which the two lower lobes are produced and envelop the large stamen, or stamens, and pistil in the bud.

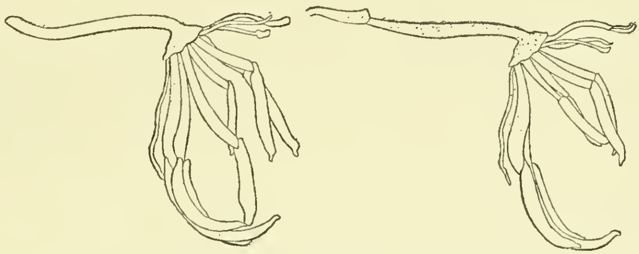
According to this arrangement about 94 species would be expected to show a dimorphism in the stamens. He fails to note the frequent difference in size of anther as well as length of filament. So far as I know he has published no list of species which he would refer to his several sections and some parts of his arrangement are not clear to me. So far as I have been able to learn from examination of descriptions of the species of the genus 69 species show more or less pronounced structural differences in the stamens, the list furnishing a very interesting study in incipient zygomorphy.

Zygomorphy as a teratological phenomenon in three species and its possible occurrence in a fourth, *S. Carolinense*, is certainly suggestive. Occurring in the forms in which it does and in a generally actinomorphic genus precludes the suggestion of atavistic reversion in these cases. The hereditary nature of many malformations, or mutations, is well known. The advantage of the projection of the lower beyond the upper stamens might be an immediate one in that the adaptation to visiting insects would become more perfect and so the aid of natural selection in the fixation of the new form would become immediately effective. Direct ecological work has been done in only one of the strongly zygomorphic forms in this genus* but this is sufficient to show the great difference in favor of the zygomorphic as compared with the

* Todd. Amer. Nat. **16**: 281–287. 1882. Harris and Kuchs, Kans. Univ. Sci. Bull. **1**: 15–41. *1 pl.* 1902.

actinomorphic flower in securing insect visits and it seems quite probable that flowers receiving occasional insect visits, as many species of Solanum evidently do, might have the frequency of these visits immediately increased upon the assumption of a zygomorphic habit.

In *S. rostratum* the form of the flower is very constant. In the large series of material which has passed through my hands I have never observed synanthy or any variation worthy of mention in the number, form, or arrangement of the stamens. It is interesting to note, however, that in *S. Amazonium* besides the floral variation noted in the descriptions of the species Penzig* says: "Ich fand häufig die Corolla durch seitliche Verschmelzung der Lappen vier- oder gar nur drei lappig. Hexamere Blüthen sind auch nicht



Androecium of Cassia occidentalis.

selten: in denselben sind dann gewöhnlich zwei lange und vier kurze Stamina vorhanden."

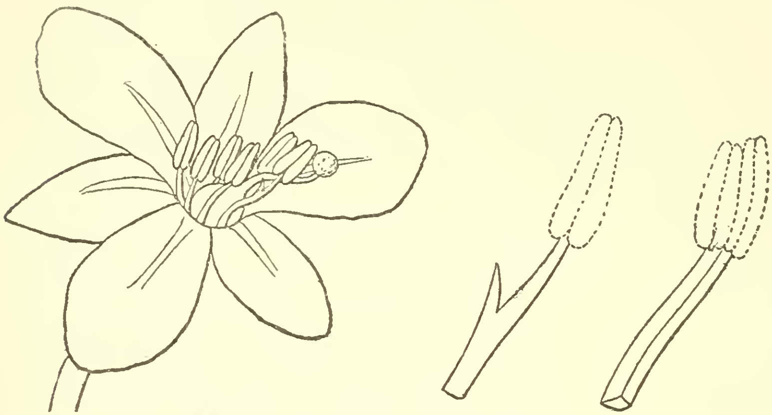
In several species of Cassia we have a zygomorphic condition in many respects very similar to that of Solanum. In *C. Marylandica* and *C. occidentalis* the androecium is composed of two large anthers on long filaments, four central smaller ones and three staminodia above and one more or less reduced stamen below the pistil between the two large stamens.

In *C. occidentalis* I have observed the transformation of one of the four smaller stamens into one of the large type. The sterile staminodia sometimes produce well-formed anthers

* Penzig, O. Pflanzen Teratologie. 2: 170.

in this species. In *C. Marylandica* one of the large stamens was partially petaloid.

It is of interest to note that in the genus Monochoria of the Pontederiaceae in which the general form of the flower resembles somewhat some of the species of Solanum, the Australian species *M. cyanea* Müll. has the stamens equal and the lower one not produced as in the other two species of the genus, but according to Bentham (Fl. Austral. 7: 72) one anther is often larger or smaller than the others. In the other two species the lower stamen is the larger, with



MONOCHORIA HASTATA. — Roxburgh.

a longer stouter filament provided with a lateral spur. As a possible origin for the lateral spur attention may be called to the description and figures given by Roxburgh * in which he states that in *M. vaginalis* the lower filament is usually broad and two-cleft, the inferior division bearing the anthers, the other nothing, and in *M. hastata* the anther of the lower stamen is much larger or double while the filament is two cleft or double.

Issued December 12, 1903.

* Roxburgh, Coromandel Plants. 2. *pl. 110, 111.*

THE GERMINATION OF PACHIRA, WITH A NOTE ON THE NAMES OF TWO SPECIES.*

J. Arthur Harris.

Systematically, the species of the genus Pachira Aubl., often passing under the generic name Carolinea Linn., have presented great difficulty. Bentham and Hooker, in the *Genera Plantarum*, place the genus in the tribe or sub-order Bombaceae with Adansonia, Bombax, etc., while Engler and Prantl, in *Die Naturlichen Pflanzenfamilien*, include Pachira Aubl., Carolinea Linn., Eriotheca and Salmalia Schott and Endl., in the genus Bombax of the Bombaceae. In considering the species of the genus the difficulty is quite great, owing to the inadequate condition of herbarium material, and considerable confusion has reigned.

In the Missouri Botanical Garden are growing some specimens of Pachira, which Dr. Trelease † has described and figured, giving a key for six more commonly cultivated species, but assigning no name to the Garden specimens on account of the impossibility of affirming or denying identity with *Carolinea affinis* as described in volume one of Martius' *Flora Brasiliensis* or Don in the first volume in his *History of Dichlamydeous Plants*. In 1898, Terracciano ‡ published an extensive paper on extra-floral nectaries in the Bombaceae, and in a footnote under *P. campestris* refers the specimens described and figured by Dr. Trelease to this species.

Early in February, 1903, my attention was attracted by eight remarkable seedlings in the propagating house and I

---

* Presented to The Academy of Science of St. Louis, November 2, 1903.

† Trelease, Wm. Notes and Observations. I. Pachira sp. Ann. Rep. Mo. Bot. Gard. 5: 154–157. *pl. 27.* 1894.

‡ Terracciano, A. I nettarii estranuziali nelle "Bombacee." R. Istituto Botanico di Palermo. Contribuzioni alla Biologia vegetale. 2: 138–191. *pls. 15–18.* 1898.

learned that they were grown from seed which had been taken a few days before from the Pachira trees above mentioned. While my series of material is not so extensive as I might wish, the observations seem to be worthy of presentation.

From the gardeners I learned that the seed was planted as soon as it had fallen from the tree, and germinated almost immediately, the young plants appearing in three or four days and making a vigorous growth. When I noticed them the hypocotyl had attained a length of about five to eight cm. and the plumule was just beginning to develop.

The fruit of *P. campestris* is an ovoid capsule attaining or somewhat surpassing the length of three inches, with a diameter of two inches or more. When ripe, it splits into five valves, each with a central septum. An axile five-winged columella bears as many rows of about five seeds each. The seeds vary considerably in size and shape owing to their compression in the capsule. Roughly speaking, they are spheroidal in form, somewhat flattened at the point of attachment, and often much more so laterally where the neighboring seeds come in contact. They have a brown ground color while the very irregular, somewhat anastomosing, white bands radiating from the hilum around the seed give it a very characteristic appearance. The crustaceous covering is thin but hard and moderately firm. The bulk of the seed is made up of one large, much convoluted, fleshy cotyledon, enclosing in its folds the rather large, thick radicle, the smaller cotyledon and the scanty, mucilaginous albumen. The larger cotyledon is more or less reniform or cordate in outline, and in the material I have examined is brought into the compass of the seed by a folding in of the distal end and of the lateral lobes which surround this and the radicle and small cotyledon which has its ventral (inner) surface applied to the inner surface of the larger cotyledon. The interstices are filled with the scanty mucilaginous albumen. The plumule is hardly developed, but the radicle is quite large.

Decaisne* describes the seed of *Pachira* as follows: " Se-

* Decaisne, J. Examen des espèces des genres *Bombax* et *Pachira*. Fl. des Serres. **23**: 43–52. 1880.

mina magna, globosa v. mutua compressione angulata; testa reticulato-venosa. Albumen ov. sublaminarum mucosarum plicis embryonis interpositarum forma; cotyledones inaequales, exterior triplicata interiorem minorem involvens." On the seeds of how many species this generic character is founded is not stated, though he examined several species in the living state. In support of the character, he refers to Tussac,* Martius† and Lynch.‡ I have not been able to consult the fourth volume of *Flore des Antilles*, but Decaisne and *Index Kewensis* retain the species *P. grandiflora* Tuss., as a good one. The form figured by Martius is *C. princeps*, a synonym of *P. aquatica*, the same species treated by Lynch. The *Pachira à fleurs blanches*, the seeds of which were figured by Doumet,§ has been described as *P. oleagina* by Decaisne. These with the *P. campestris* here described make four of the thirty-one species recognized by *Index Kewensis* which have unequal cotyledons, and perhaps Decaisne has examined other species the names of which are not given.

The early stages of development of the seedling I have not been able to study, since germination was quite well advanced when I first observed my material and old seeds from the herbarium did not germinate. When first noticed, the stout green hypocotyl was from five to eight cm. in length in the various examples, and the large green convoluted cotyledons well expanded, but the plumule had hardly begun its development. The small cotyledon is not exactly opposite the larger but is attached somewhat above it. Five of the seedlings at this stage of development (Pl. IX, 5, 6, 7. Pl. X, 9, Pl. XI, 10) as well as another, the figure of which was made somewhat later (Pl. IX, 4), are figured, and from these figures it will be seen that there is a very good series of forms extending from the one in fig. 4 where the cotyledons are almost equal in size, through those represented in figs. 10, 9, 5, 6 to fig. 7 where the small cotyledon

---

* Tussac, F. R. Fl. des Antilles. **4.** *pl. 4.*

† Martius. Nov. Gen. Sp. Pl. **1.** *pl. 56.*

‡ Lynch, R. I. On the seed-structure and germination of *Pachira aquatica*. Jour. Linn. Soc. **17**: 147–148. *pl. 8.* 1880.

§ Doumet, N. Le Pachira (Carolinea) à Fleurs Blanches. Rev. Horticole. **1866**: 208–211. *fig. 24–33. pl. 1.* 1866.

is absent. A detailed description of the seedlings is unnecessary, since the figures are self-explanatory. The plumule develops very rapidly when it once begins and after the first lanceolate leaf the leaves are usually five foliolate and very similar in form to those of the mature individuals. The cotyledons are persistent for about three months, a surprising point of observation on the material available for this study being that in some cases the smaller cotyledon remained on the plant the longer. The dilatation of the base of the main axis, so prominent in the older individuals, soon exhibits itself in the seedlings, the hypocotyl at the end of five months being quite strongly developed, the expansion, however, being quite uniform throughout the greater part of the length to near the prominent, brown, cotyledonary scars, where the brownish, striated hypocotyl is rapidly attenuated into the smooth, green, epicotyledonary internodes.

So far as I am able to ascertain, the germination of Pachira has been mentioned in the literature four times. Doumet * describes and figures fruit, seed and abnormal seedlings of a Pachira of the specific name of which he was uncertain. Lynch † describes and figures the seed and seedlings of *P. aquatica* and figures an abnormal seedling of *Pachira* sp. Harz, ‡ in the second volume of his *Landwirthschaftliche Samenkunde* (1885) mentions *P. aquatica* as one of many forms of Dicotyledonous plants with one or both cotyledons rudimentary. Lubbock || states with a reference to Lynch's paper, that in *P. aquatica* the cotyledons are subterranean, but this is evidently an oversight on his part, since neither the text nor the plate of Lynch's paper justifies such a statement.

In working over the material for this paper, my attention was called to a point in the nomenclature of the forms which is deserving of attention. *Carolinea campestris* was briefly described by Martius (Nov. Gen. et Sp. Pl. **1** : 86) and from this very short description the other descriptions (Don.

* Doumet. loc. cit.

† Lynch. loc. cit.

‡ According to the review in Just's Jahresbericht.

|| Lubbock, Sir John. A Contribution to our Knowledge of Seedlings. **1** : 246. 1892.

Hist. Dich. Pl. **1** : 570. — Decaisne. Fl. des Serres. **23** : 52) are evidently taken, Decaisne placing it among the inadequately-known species of Pachira. Terracciano bases his identification of *P. campestris* upon an examination of the specimens collected and described by Martius, and it is upon his authority (R. Ist. Bot. Pal. Cont. Biol. Veg. **2** : 168) that my material is referred to this species.

In his examination of the species of Pachira and Bombax, Decaisne describes as new *P. oleagina* from material cultivated in the Hamma Botanical Gardens of Algeria and refers to this species the *Pachira à fleurs blanches* of Doumet (Rev. Hort. 1866 : 208. Not *P. alba*, Lodd. or Hook.).

In the vegetative characteristics,— the straight stem strongly swollen at the base and provided with several spreading branches at the top, rather smooth and green throughout the most of its length and becoming grayish only near the base, the form and division of the leaflets, — the Missouri Botanical Garden material agrees well with Doumet's description, as it also does for the most part in the time of putting forth new leaves. In both, the flowers open at night and persist for but a very short time. I have not been so fortunate as to see fresh flowers, but those who have seen such tell me that the resemblance to Doumet's colored plate is very close and so far as I can determine from descriptions and the herbarium material available, agreement is quite good though in the androecium there seems to be considerable difference, Doumet stating that the stamens in *Pachira à fleurs blanches* are united at the base into five bundles, while Trelease (loc. cit.) places his material with those in which the stamen tube is divided into ten clusters. There seem to be other minor differences, but in the main the resemblance is very close. Fruit and seed in the Garden herbarium agree perfectly with the excellent text figures in M. Doumet's paper, so that I have little doubt of the identity of *P. campestris* (Mart.) Decsne. and *P. oleagina* Decsne. In this case *P. campestris* has priority.

Polyembryony seems to be common in *P. campestris*. Doumet gives excellent figures of more than one plantlet produced from a single seed and while the eight seedlings which first attracted my attention were normal, dissection of nine seeds from a single fruit collected in 1893(?) shows more than one embryo in three cases, while the others were with but one. Lynch in his paper figures the seedling of a *Pachira* sp. (Pl. VIII, fig. 7) showing the adherence of two others of arrested growth, resulting from the production of several embryos in one seed. Unfortunately the size of this seedling is not indicated on the plate, but in general appearance it agrees quite well with young stages of *P. campestris* and it perhaps belongs to this species.

Some very striking differences are noticed between the germination of *P. campestris* and *P. aquatica*. In both there is one large and one small cotyledon, the smaller being in both a little above the other. In *P. aquatica*, according to Lynch, the small cotyledon soon falls away while the larger persists for a long time, but in two or three cases in *P. campestris* the smaller cotyledon persisted the longer. The most striking point of difference is in the relative development of hypocotyl and epicotyl in the two forms. In *P. aquatica*, according to the plate given by Lynch, the hypocotyl is developed hardly at all, the cotyledons remaining almost if not quite on the ground and but a short distance above the lateral rootlets, while the epicotyl undergoes a very extensive development extending for a considerable distance before foliage leaves are borne, while these are separated by fairly long internodes, the whole presenting a very slender, graceful appearance. In *P. campestris* the case is quite different. The cotyledons are at once carried up for some distance on a strongly developed hypocotyl, and it is some time before the plumule undergoes much development. When it does, it does not reach a length comparable with that figured for *P. aquatica*, while the large foliage leaves are separated by but comparatively short internodes, the whole plant giving the impression of a much stouter, more broadly spreading form than *P. aquatica*. What may be the significance of these differences would be hard to suggest, but it would be of great interest to know the ecological conditions under which the two species are to be found, since in some cases it seems that the habit of the seedling may be traced to differences in ecological conditions. From a taxonomic standpoint it is certainly worthy of note, and especially so in a genus presenting the difficulties which Pachira does. The comparative development of hypocotyl and epicotyl is interesting when we compare the structure of the seeds of *C. insignis* (= *P. aquatica*) as figured by Martius with the seed of *P. campestris*, since in both the radicle and the plumule seem to show about the same degree of development.

The reduction of *P. oleagina* will take one from the list of nominal species known from recorded examination to have one cotyledon larger than the other.

EXPLANATION OF ILLUSTRATIONS.

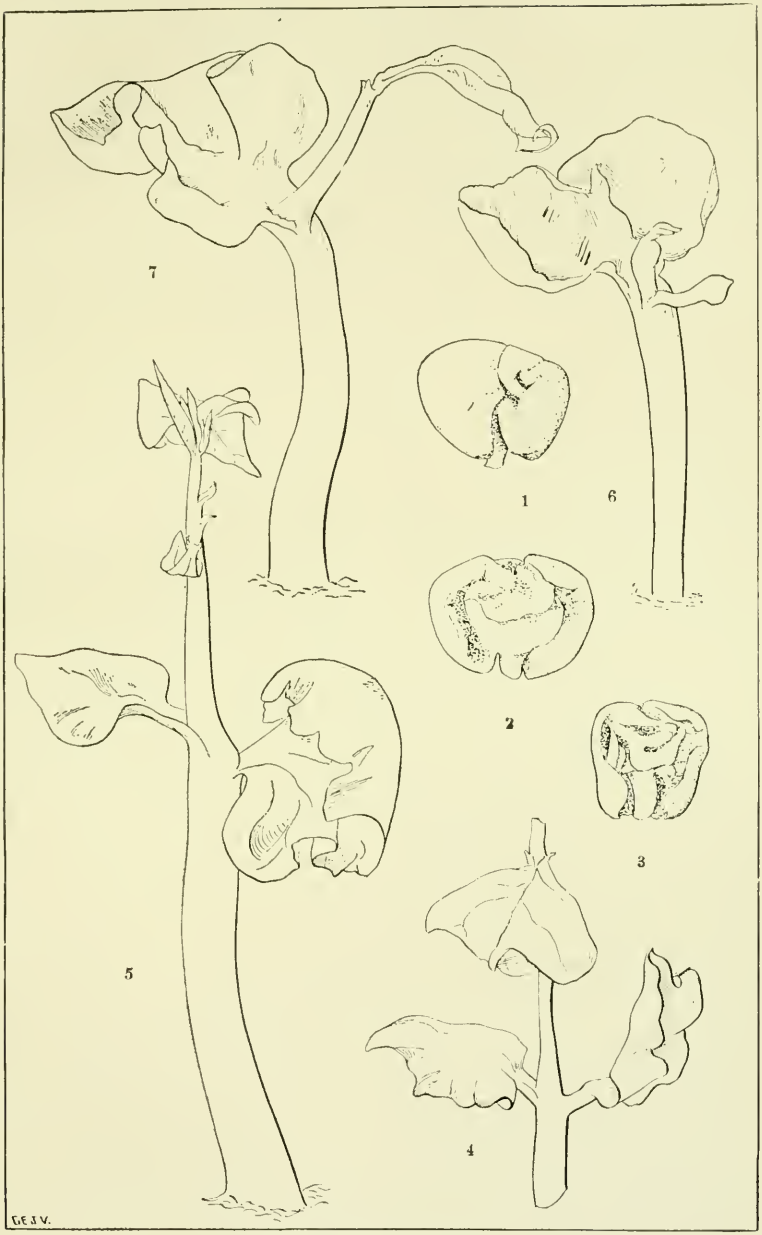
Plates IX–XI.

Plate IX. — 1, 2. Embryo of Pachira viewed from dorsal and ventral surface of large cotyledon. — 3, Another seed viewed from inner surface of large cotyledon: 2 and 3 with lateral lobes somewhat spread apart to show small cotyledon. — 5–7. Young seedlings. — 4. A portion of a somewhat older specimen, showing general habit and stages in the reduction of one cotyledon. — All $\times$ 1.

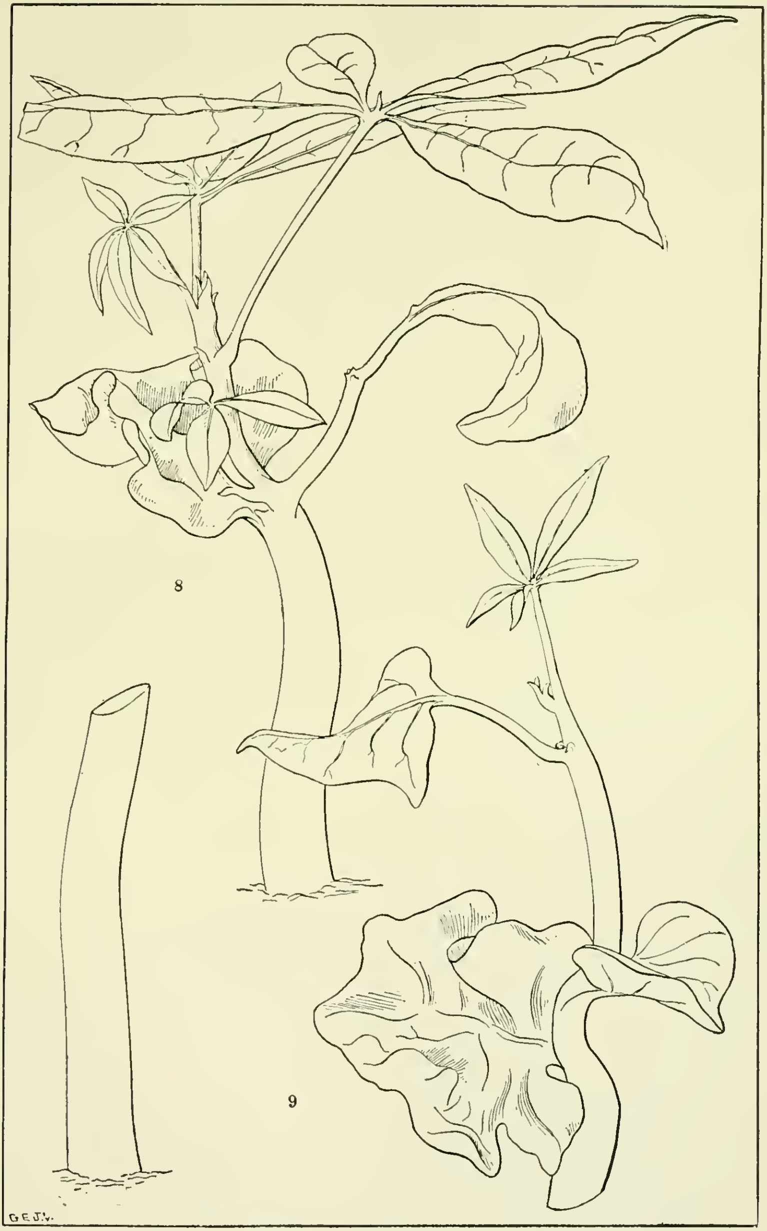
Plate X. — 8. Later stage of No. 7, showing abnormal development. — 9. Seedling of same age as those on Plate IX showing normal development of plumule. — All $\times$ 1.

Plate XI. — 10–12. Three stages in development of a seedling: 10 as in Plate IX; 11 several days older; 12 some months older showing dilatation at base of stem. — 10 $\times$ 1. — 11, 12 $\times$ ½.

Issued December 12, 1903.



SEEDLINGS OF PACHIRA.



SEEDLINGS OF PACHIRA.

SEEDLINGS OF PACHIRA.

PUBLICATIONS.

The following publications of the Academy are offered for sale at the net prices indicated. Applications should be addressed to The Librarian, The Academy of Science of St. Louis, St. Louis, Mo.

TRANSACTIONS (in octavo).

Vol.	Number.	Price per number.	Price per vol.	Price in set.
1	1* 2† 3, 4	.... $4.00 2.00 each.	$7.50 (Nos. 2-4 only.)	$7.00 (Nos. 2-4 only.)
2	1 to 3	2.00 each.	5.50	5.00
3	1 to 4	2.00 each.	7.50	7.00
4	1 to 4	2.00 each.	7.50	7.00
5	1-2, 3-4	4.00 each. (double numbers)	7.50	7.00
6‡	1, 2, 6, 8, 10, 11, 16, 17 4, 5, 7, 13, 14, 15, 18 3, 9 12	25 cts. each. 50 cts. each. 75 cts. each. $1.00	7.50	7.00
7‡	2, 3, 4, 6, 7, 8, 13, 15, 16, 18, 19 5, 9 to 12, 14, 20 17 1	25 cts. each. 50 cts. each. 75 cts. $1.00	7.50	7.00
8‡	1, 3 to 6 8, 10, 12 2, 7, 9, 11	25 cts. each. 50 cts. each.	3.75	3.50
9‡	1, 3, 4, 7, 9 2, 5, 8 6	25 cts. each. 50 cts. each. $1.25	3.75	3.50
10‡	9 2, 4, 5, 10 1 3, 6, 7, 8, 11	10 cts. 25 cts. each. 40 cts. 50 cts. each.	3.75	3.50
11‡	2, 3 5–8, 10, 11 1 4 9	15 cts. each. 25 cts. each. 45 cts. 75 cts. 1.00	3.75	3.50
12‡	1, 9, 10 5 3, 8 2, 4, 6, 7	25 cts. each. 30 cts. 35 cts. each. 50 cts. each.	3.75	3.50

MEMOIRS (in quarto).

Contributions to the archaeology of Missouri, by the Archaeological Section. Part I. Pottery. 1880. $2.00.

The total eclipse of the sun, January 1, 1889. A report of the observations made by the Washington University Eclipse Party, at Norman, California. 1891. $2.00.

* Supply exhausted.

† Can be sold only to purchasers of the entire volume,— so far as this can be supplied.

‡ Each number is a brochure containing one complete paper (or rarely two).

Transactions of The Academy of Science of St. Louis.

VOL. XIII. No. 9.

TITLE-PAGE, PREFATORY MATTER AND INDEX.
RECORD FROM JAN. 1 to DEC. 31, 1903.

Issued February 9, 1904.

LIST OF AUTHORS.

GENERAL INDEX.

INDEX TO GENERA.

PUBLICATIONS.

The following publications of the Academy are offered for sale at the net prices indicated. Applications should be addressed to The Librarian, The Academy of Science of St. Louis, 3817 Olive St., St. Louis, Mo.

TRANSACTIONS (in octavo).

Vol.	Number.	Price per number.	Price per vol.	Price in set.
1	1* 2† 3, 4	.... $4.00 2.00 each.	$7.50 (Nos. 2-4 only.)	$7.00 (Nos. 2-4 only.)
2	1 to 3	2.00 each.	5.50	5.00
3	1 to 4	2.00 each.	7.50	7.00
4	1 to 4	2.00 each.	7.50	7.00
5	1-2, 3-4	4.00 each. (double numbers)	7.50	7.00
6‡	1, 2, 6, 8, 10, 11, 16, 17 4, 5, 7, 13, 14, 15, 18 3, 9 12	25 cts. each. 50 cts. each. 75 cts. each. $1.00	7.50	7.00
7‡	2, 3, 4, 6, 7, 8, 13, 15, 16, 18, 19 5, 9 to 12, 14, 20 17 1	25 cts. each. 50 cts. each. 75 cts. $1.00	7.50	7.00
8‡	1, 3 to 6 8, 10, 12 2, 7, 9, 11	25 cts. each. 50 cts. each.	3.75	3.50
9‡	1, 3, 4, 7, 9 2, 5, 8 6	25 cts. each. 50 cts. each. $1.25	3.75	3.50
10‡	9 2, 4, 5, 10 1 3, 6, 7, 8, 11	10 cts. 25 cts. each. 40 cts. 50 cts. each.	3.75	3.50
11‡	2, 3 5-8, 10, 11 1 4 9	15 cts. each. 25 cts. each. 45 cts. 75 cts. 1.00	3.75	3.50
12‡	1, 9, 10 5 3, 8 2, 4, 6, 7	25 cts. each. 35 cts. 45 cts. each. 50 cts. each.	3.75	3.50
13‡	2, 3, 5-9 4 1	25 cts. each. 75 cts. 1.50	3.75	3.50

MEMOIRS (in quarto).

Contributions to the archaeology of Missouri, by the Archaeological Section. Part I. Pottery. 1880. $2.00.

The total eclipse of the sun, January 1, 1889. A report of the observations made by the Washington University Eclipse Party, at Norman, California. 1891. $2.00.

---

* Supply exhausted.

† Can be sold only to purchasers of the entire volume,— so far as this can be supplied.

‡ Each number is a brochure containing one complete paper (or rarely two).