# PROCEEDINGS

OF

# THE AMERICAN ASSOCIATION

FOR THE

## ADVANCEMENT OF SCIENCE

FOR THE FORTY-FIRST MEETING.

HELD AT

## ROCHESTER, N. Y.,

AUGUST, 1892.

SALEM:
PUBLISHED BY THE PERMANENT SECRETARY.
DECEMBER, 1892.

EDITED BY
FREDERIC W. PUTNAM,
*Permanent Secretary.*

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# OFFICERS

OF THE

# ROCHESTER MEETING.

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JOSEPH LECONTE, Berkeley, California.

## VICE-PRESIDENTS.

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FOR THE

# ROCHESTER MEETING.

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*From the Association at Large.*—A fellow elected from each section.—(The following hold over until their successors are chosen), G. W. HOUGH, Evanston, Ill. (A); W. A. ROGERS, Waterville, Me. (B); WM. L. DUDLEY, Nashville, Tenn. (C); S. W. ROBINSON, Columbus, O. (D); C. H. HITCHCOCK, Hanover, N. H. (E); THOMAS MORONG, New York, after Aug. 21, A. H. TUTTLE, Univ. of Virginia (F); DANIEL G. BRINTON, Philadelphia, Pa. (H); MANLY MILES, Lansing, Mich. (I).

## LOCAL COMMITTEE

# FOR THE ROCHESTER MEETING.

---

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## COMMITTEE ON AMERICAN MICROSCOPICAL SOCIETY.

**Dr. M. L. MALLORY, *Chairman*. Prof. C. W. DODGE, *Secretary*, and twenty-four other gentlemen.**

## COMMITTEE ON BOTANICAL CLUB.

**WILLIAM STREETER, *Chairman*. C. C. LANEY, *Secretary*, and fifteen other gentlemen and ladies.**

## LOCAL COMMITTEE AT LARGE.

**Consisting of one hundred and seventeen gentlemen and ladies.**

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1. *Auditors.*

THOMAS MEEHAN, Germantown. | B. A. GOULD, Cambridge.

2. *Honorary Agent of Transportation to act with the Local Committees.*

HENRY GANNETT, Washington.

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F. W. CLARKE, Washington,
A. R. LEEDS, Hoboken,
A. A. JULIEN, New York,
J. W. LANGLEY, Pittsburgh,
A. B. PRESCOTT, Ann Arbor.
ALFRED TUCKERMAN, Newport.

4. *Committee to apply to Congress for a Reduction of the Tariff on Scientific Books and Apparatus.*

E. D. COPE, Philadelphia,
J. R. EASTMAN, Washington,
S. A. FORBES, Champaign.

5. *Committee to memorialize Congress to take steps for the Preservation of Archæologic Monuments on the public lands.*

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6. *Committee on Water Analysis.*

G. C. CALDWELL, Ithaca,
J. A. MYERS, Agricultural Coll., Miss.,
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J. W. LANGLEY, Ann Arbor,
W. P. MASON, Troy,
W. H. SEAMAN, Washington.

7. *Committee on the Maintenance of Timberlands and on the Development of the Natural Resources of the Country.*

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E. W. HILGARD, Berkeley,
C. E. BESSEY, Lincoln,
B. E. FERNOW, Washington,
WILLIAM SAUNDERS, Ottawa.

[1] All Committees are expected to present their reports to the COUNCIL not later than the fourth day of the meeting. Committees sending their reports to the Permanent Secretary one month before a meeting can have them printed for use at the meeting.

8. *Committee to secure an American Table at the International Marine Biological Station at Naples, Italy.*

C. W. STILES, Washington,
E. D. COPE, Philadelphia,
E. S. MORSE, Salem,
W. R. DUDLEY, Palo Alto.

9. *Committee on Biological Nomenclature.*

GEORGE L. GOODALE, Cambridge,
J. M. COULTER, Crawfordsville,
C. S. MINOT, Boston,
THEODORE GILL, Washington,
S. H. GAGE, Ithaca.

10. *Committee on Standards for Astronomical and Physical Units.*

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E. C. PICKERING, Cambridge,
T. C. MENDENHALL, Washington,
W. R. WARNER, Cleveland,
G. N. SAEGMULLER, Washington,
WILLIAM HARKNESS, Washington,
J. A. BRASHEAR, Pittsburg,
ALVIN G. CLARK, Cambridge.

11. *Committee on the Endowment of Research Fund.*

| | | |
|---|---|---|
| JOHN A. BRASHEAR, Pittsburgh, | Section | A, *Chairman.* |
| FRANCIS E. NIPHER, St. Louis, | " | B, |
| S. A. LATTIMORE, Rochester, | " | C, |
| R. H. THURSTON, Ithaca, | " | D, |
| JOHN J. STEVENSON, New York, | " | E, |
| C. V. RILEY, Washington, | " | F, |
| ——— ——— | " | G, |
| THOMAS WILSON, Washington, | " | H, |
| EDMUND J. JAMES, Philadelphia, | " | I, |

12. *Committee to confer with the Director-General of the World's Columbian Exposition to secure special headquarters during the Exposition for the sciences represented by the nine sections of the Association.*

THE NINE SECRETARIES OF THE SECTIONS FOR THE MEETING OF 1893.

13. *Committee on a Table at the proposed Marine Biological Station at Jamaica.*

A. H. TUTTLE, Univ. of Virginia,
E. S. MORSE, Salem,
B. D. HALSTED, New Brunswick,
C. W. STILES, Washington,
N. L. BRITTON, New York.

14. *Committee on the Preservation of the Ancient Earthworks near Anderson, Indiana.*

W. H. HOLMES, Washington,
F. W. PUTNAM, Cambridge,
O. T. MASON, Washington,
D. G. BRINTON, Philadelphia,
A. W. BUTLER, Brookville.

15. *Committee of the Sections to coöperate with the World's Congress Auxiliary of the World's Columbian Exposition for the holding of International Scientific Congresses during the Exposition.*

SECTION A.—SIMON NEWCOMB, Washington; H. A. NEWTON, New Haven; E. C. PICKERING, Cambridge; S. P. LANGLEY, Washington; R. S. WOODWARD, Washington; T. H. SAFFORD, Williamstown; S. C. CHANDLER, Cambridge.

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SECTION D.—E. L. CORTHELL, Chicago; J. E. DENTON, Hoboken; HENRY R. TOWNE, Stamford; R. H. THURSTON, Ithaca; BENEZETTE WILLIAMS, Chicago.

SECTION E.—T. C. CHAMBERLAIN, Chicago; G. K. GILBERT, Washington; H. S. WILLIAMS, New Haven; J. C. BRANNER, Menlo Park; R. D. SALISBURY, Beloit; C. A. WALCOTT, Washington; J. F. WHITEAVES, Ottawa; E. A. SMITH, University of Alabama; W. H. WINCHELL, Minneapolis; G. H. WILLIAMS, Baltimore; W J MCGEE, Washington.

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These several sub-committees have the power to fill vacancies and to add to their numbers.

## OFFICERS ELECTED

FOR THE

# MADISON MEETING.

AUGUST, 1893.

[*The first General Session of this Meeting will be on Thursday, August* 17.]

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### PRESIDENT.

WILLIAM HARKNESS, Washington, D. C.

### VICE-PRESIDENTS.

A. **Mathematics and Astronomy**—C. L. DOOLITTLE, South Bethlehem, Pa.
B. **Physics**—E. L. NICHOLS, Ithaca, N. Y.
C. **Chemistry**—EDWARD HART, Easton, Pa.
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E. **Geology and Geography**—CHAS. D. WALCOTT, Washington, D. C.
F. **Zoology**—HENRY F. OSBORN, New York, N. Y.
G. **Botany**—CHARLES E. BESSEY, Lincoln, Neb.
H. **Anthropology**—J. OWEN DORSEY, Tacoma, Md.
I. **Economic Science and Statistics**—WILLIAM H. BREWER, New Haven, Conn.

### PERMANENT SECRETARY.

F. W. PUTNAM, Cambridge (office Salem), Mass.

### GENERAL SECRETARY.

T. H. NORTON, Cincinnati, Ohio.

### SECRETARY OF THE COUNCIL.

H. L. FAIRCHILD, Rochester, N. Y.

### SECRETARIES OF THE SECTIONS.

A. **Mathematics and Astronomy**—ANDREW W. PHILLIPS, New Haven, Conn.
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C. **Chemistry**—J. U. NEF, Chicago, Ill.
D. **Mechanical Science and Engineering**—D. S. JACOBUS, Hoboken, N. J.
E. **Geology and Geography**—ROBERT T. HILL, Austin, Texas.
F. **Zoology**—L. O. HOWARD, Washington, D. C.
G. **Botany**—F. V. COVILLE, Washington, D. C.
H. **Anthropology**—WARREN K. MOOREHEAD, Xenia, O.
I. **Economic Science and Statistics**—NELLIE S. KEDZIE, Manhattan, Kas.

### TREASURER.

WILLIAM LILLY, Mauch Chunk, Pa.

## MEETINGS AND OFFICERS OF THE AMERICAN ASSOCIATION OF GEOLOGISTS AND NATURALISTS.

| MEETING. | DATE. | PLACE. | CHAIRMAN. | SECRETARY. | ASSIS'T SEC'Y. | TREASURER. |
|---|---|---|---|---|---|---|
| 1st | April 2, 1840, | Philadelphia, | Edward Hitchcock,* | L. C. Beck,* | | |
| 2d | April 5, 1841, | Philadelphia, | Benjamin Silliman,* | L. C. Beck,* | B. Silliman, jr.,*<br>C. B. Trego,* | |
| 3d | April 25, 1842, | Boston, | S. G. Morton,* | C. T. Jackson,* | J. D. Whitney,<br>M. B. Williams,* | |
| 4th | April 26, 1843, | Albany, | Henry D. Rogers,* | B. Silliman, jr.,* | | John Locke.* |
| 5th | May 8, 1844, | Washington, | John Locke,* | B. Silliman, jr.,*<br>O. P. Hubbard, | | Douglas Houghton.* |
| 6th | April 30, 1845, | New Haven, | Wm. B. Rogers,* | B. Silliman, jr.,*<br>J. Lawrence Smith,* | | Douglas Houghton.* |
| 7th | Sept. 2, 1846, | New York, | C. T. Jackson,* | B. Silliman, jr.,* | | E. C. Herrick.* |
| 8th | ept. 20, 1847, | Boston, | Wm. B. Rogers,†* | Jeffries Wyman,* | | B. Silliman, jr.* |

* Deceased.

† Professor ROGERS, as chairman of this last meeting, called the first meeting of the new Association to order and presided until it was fully organized by the adoption of a constitution. As he was thus the first presiding officer of the new Association, it was directed at the Hartford meeting that his name be placed at the head of the Past Presidents of the American Association for the Advancement of Science.

| MEETINGS. | PLACE. | DATE. | MEMBERS IN ATTENDANCE. | NUMBER OF MEMBERS. |
|---|---|---|---|---|
| 1. | Philadelphia | Sept. 20, 1848 | ? | 461 |
| 2. | Cambridge | Aug. 14, 1849 | ? | 540 |
| 3. | Charleston | Mar. 12, 1850 | ? | 622 |
| 4. | New Haven | Aug. 19, 1850 | ? | 704 |
| 5. | Cincinnati | May 5, 1851 | 87 | 800 |
| 6. | Albany | Aug. 19, 1851 | 194 | 769 |
| 7. | Cleveland | July 28, 1853 | ? | 940 |
| 8. | Washington | April 26, 1854 | 168 | 1004 |
| 9. | Providence | Aug. 15, 1855 | 166 | 605 |
| 10. | 2nd Albany | Aug. 20. 1856 | 381 | 722 |
| 11. | Montreal | Aug. 12, 1857 | 351 | 946 |
| 12. | Baltimore | April 28, 1858 | 190 | 962 |
| 13. | Springfield | Aug. 3, 1859 | 190 | 862 |
| 14. | Newport | Aug. 1, 1860 | 135 | 644 |
| 15. | Buffalo | Aug. 15, 1866 | 79 | 637 |
| 16. | Burlington | Aug. 21, 1867 | 73 | 415 |
| 17. | Chicago | Aug. 5, 1868 | 259 | 686 |
| 18. | Salem | Aug. 18, 1869 | 244 | 511 |
| 19. | Troy | Aug. 17, 1870 | 188 | 536 |
| 20. | Indianapolis | Aug. 16, 1871 | 196 | 668 |
| 21. | Dubuque | Aug. 15, 1871 | 164 | 610 |
| 22. | Portland | Aug. 20. 1873 | 195 | 670 |
| 23. | Hartford | Aug. 12, 1874 | 224 | 722 |
| 24. | Detroit | Aug. 11, 1875 | 165 | 807 |
| 25. | 2nd Buffalo | Aug. 23, 1876 | 215 | 867 |
| 26. | Nashville | Aug. 29, 1877 | 173 | 953 |
| 27. | St. Louis | Aug. 21, 1878 | 134 | 962 |
| 28. | Saratoga | Aug. 27, 1879 | 256 | 1030 |
| 29. | Boston | Aug. 25, 1880 | 997 | 1555 |
| 30. | 2nd Cincinnati | Aug. 17, 1881 | 500 | 1699 |
| 31. | 2nd Montreal | Aug. 23, 1882 | 937 | 1922 |
| 32. | Minneapolis | Aug. 15, 1883 | 328 | 2033 |
| 33. | 2nd Philadelphia | Sept. 3, 1884 | 1261* | 1981 |
| 34. | Ann Arbor | Aug. 26, 1885 | 364 | 1956 |
| 35. | 3d Buffalo | Aug. 18, 1886 | 445 | 1886 |
| 36. | New York | Aug. 10, 1887 | 729 | 1956 |
| 37. | 2nd Cleveland | Aug. 14, 1888 | 342 | 1964 |
| 38. | Toronto | Aug. 26, 1889 | 424 | 1952 |
| 39. | 2d Indianapolis | Aug. 19, 1890 | 364 | 1944 |
| 40. | 2d Washington | Aug. 19, 1891 | 653† | 2054 |
| 41. | Rochester | Aug. 17, 1892 | 456 | 2037 |
| 42. | Madison | Aug. 17, 1893 | | |

*Including members of the British Association and other foreign guests.
†Including twenty-four foreign Honorary members for the meeting.

## OFFICERS OF THE MEETINGS OF THE ASSOCIATION.

[The number before the name is that of the meeting; the year of the meeting follows the name; the asterisk after a name indicates that the member is deceased.]

### PRESIDENTS.

1. W. C. Redfield,* 1848.
2. Joseph Henry,* 1849.

3, 4, 5. A. D. Bache,* March meeting, 1850, in absence of Joseph Henry. August meeting, 1850. May meeting, 1851.

6. Louis Agassiz,* August meeting, 1851.

(No meeting in 1852).

7. Benjamin Pierce,* 1853.
8. James D. Dana, 1854.
9. John Torrey,* 1855.
10. James Hall, 1856.

11, 12. Alexis Caswell,* 1857, in place of J. W. Bailey, deceased. 1858, in absence of Jeffries Wyman.

13. Stephen Alexander,* 1859.
14. Isaac Lea,* 1860.

(No meetings for 1861–65).

15. F. A. P. Barnard,* 1866.
16. J. S. Newberry, 1867.
17. B. A. Gould, 1868.
18. J. W. Foster,* 1869.
19. T. Sterry Hunt,* 1870, in the absence of Wm. Chauvenet.
20. Asa Gray,* 1871.
21. J. Lawrence Smith*, 1872.
22. Joseph Lovering,* 1873.
23. J. L. LeConte,* 1874.
24. J. E. Hilgard,* 1875.
25. William B. Rogers,* 1876.
26. Simon Newcomb, 1877.
27. O. C. Marsh, 1878.
28. G. F. Barker, 1879.
29. Lewis H. Morgan,* 1880.
30. G. J. Brush, 1881.
31. J. W. Dawson, 1882.
32. C. A. Young, 1883.
33. J. P. Lesley, 1884.
34. H. A. Newton, 1885.
35. Edward S. Morse, 1886.
36. S. P. Langley, 1887.
37. J. W. Powell, 1888.
38. T. C. Mendenhall, 1889.
39. G. Lincoln Goodale, 1890.
40. Albert B. Prescott, 1891.
41. Joseph LeConte, 1892.
42. William Harkness, 1893.

## VICE-PRESIDENTS.

There were no vice-presidents until the 11th meeting when there was a single vice-president for each meeting. At the 24th meeting the Association met in Sections A and B, each presided over by a vice-president. At the 31st meeting nine sections were organized, each with a vice-president as its presiding officer. In 1886, Section G (Microscopy) was given up. In 1892, the Section of Botany was organized as Section G.

### 1857–1874.

11. ALEXIS CASWELL,* 1857, acted as President.
12. JOHN E. HOLBROOK,* 1858, not present.
13. EDWARD HITCHCOCK,* 1859.
14. B. A. GOULD, 1860.
15. A. A. GOULD,* 1866, in absence of R. W. GIBBES.
16. WOLCOTT GIBBS, 1867.
17. CHARLES WHITTLESEY,* 1868.
18. OGDEN N. ROOD, 1869.
19. T. STERRY HUNT,* 1870, acted as President.
20. G. F. BARKER, 1871.
21. ALEXANDER WINCHELL,* 1872.
22. A. H. WORTHEN,* 1873, not present.
23. C. S. LYMAN,* 1874.

### 1875–1881.

*Section A.—Mathematics, Physics and Chemistry.*

24. H. A. NEWTON, 1875.
25. C. A. YOUNG, 1876.
26. R. H. THURSTON, 1877, in the absence of E. C. PICKERING.
27. R. H. THURSTON, 1878.
28. S. P. LANGLEY, 1879.
29. ASAPH HALL, 1880.
30. WILLIAM HARKNESS, 1881, in the absence of A. M. MAYER.

*Section B.—Natural History.*

24. J. W. DAWSON, 1875.
25. EDWARD S. MORSE, 1876.
26. O. C. MARSH, 1877.
27. AUG. R. GROTE, 1878.
28. J. W. POWELL, 1879.
29. ALEXANDER AGASSIZ, 1880.
30. EDWARD T. COX, 1881, in the absence of GEORGE ENGELMANN.

### CHAIRMEN OF SUBSECTIONS, 1875–1881.

*Subsection of Chemistry.*

24. S. W. JOHNSON, 1875.
25. G. F. BARKER, 1876.
26. N. T. LUPTON, 1877.
27. F. W. CLARKE, 1878.
28. F. W. CLARKE, 1879, in the absence of IRA REMSEN.
29. J. M. ORDWAY, 1880.
30. G. C. CALDWELL, 1881, in the absence of W. R. NICHOLS.

*Subsection of Microscopy.*

25. R. H. WARD, 1876.
26. R. H. WARD, 1877.
27. R. H. WARD, 1878, in the absence of G. S. BLACKIE.
28. E. W. MORLEY, 1879.
29. S. A. LATTIMORE, 1880.
30. A. B. HERVEY, 1881.

*Subsection of Anthropology.*

24. LEWIS H. MORGAN,* 1875.
25. LEWIS H. MORGAN,* 1876.
26. DANIEL WILSON,* 1877, not present.
27. United with Section B.
28. DANIEL WILSON,* 1879.
29. J. W. POWELL, 1880.
30. GARRICK MALLERY, 1881.

*Subsection of Entomology.*

30. J. G. MORRIS, 1881.

VICE-PRESIDENTS OF SECTIONS, 1882–

*Section A.—Mathematics and Astronomy.*

31. W. A. ROGERS, 1882, in the absence of WILLIAM HARKNESS.
32. W. A. ROGERS, 1883.
33. H. T. EDDY, 1884.
34. WILLIAM HARKNESS, 1885, in the absence of J. M. VAN VLECK.
35. J. W. GIBBS, 1886.
36. J. R. EASTMAN, 1887, in place of W. FERREL, resigned.
37. ORMOND STONE, 1888.
38. R. S. WOODWARD, 1889.
39. S. C. CHANDLER, 1890.
40. E. W. HYDE, 1891.
41. J. R. EASTMAN, 1892.
42. C. L. DOOLITTLE, 1893.

*Section C.—Chemistry.*

31. H. C. BOLTON, 1882.
32. E. W. MORLEY, 1883.
33. J. W. LANGLEY, 1884.
34. N. T. LUPTON, 1885, in absence of W. R. NICHOLS.
35. H. W. WILEY, 1886.
36. A. B. PRESCOTT, 1887.
37. C. E. MUNROE, 1888.
38. W. L. DUDLEY, 1889.
39. R. B. WARDER, 1890.
40. R. C. KEDZIE, 1891.
41. ALFRED SPRINGER, 1892.
42. EDWARD HART, 1893.

*Section B.—Physics.*

31. T. C. MENDENHALL, 1882.
32. H. A. ROWLAND, 1883
33. J. TROWBRIDGE, 1884.
34. S. P. LANGLEY, 1885, in place of C. F. BRACKETT, resigned.
35. C. F. BRACKETT, 1886.
36. W. A. ANTHONY, 1887.
37. A. A. MICHELSON, 1888.
38. H. S. CARHART, 1889.
39. CLEVELAND ABBE, 1890.
40. F. E. NIPHER, 1891.
41. B. F. THOMAS, 1892.
42. E. L. NICHOLS, 1893.

*Section D.—Mechanical Science and Engineering.*

31. W. P. TROWBRIDGE,* 1882.
32. DE VOLSON WOOD, 1883, absent, but place was not filled.
33. R. H. THURSTON, 1884.
34. J. BURKITT WEBB, 1885.
35. O. CHANUTE, 1886.
36. E. B. COXE, 1887.
37. C. J. H. WOODBURY, 1888.
38. JAMES E. DENTON, 1889.
39. JAMES E. DENTON. 1890.
40. THOMAS GRAY, 1891.
41. J. B. JOHNSON, 1892.
42. S. W. ROBINSON, 1893.

VICE-PRESIDENTS OF SECTIONS, CONTINUED.

*Section E.—Geology and Geography.*

31. E. T. COX, 1882.
32. C. H. HITCHCOCK, 1883.
33. N. H. WINCHELL, 1884.
34. EDWARD ORTON, 1885.
35. T. C. CHAMBERLIN, 1886.
36. G. K. GILBERT, 1887.
37. GEORGE H. COOK,* 1888.
38. CHARLES A. WHITE, 1889.
39. JOHN C. BRANNER, 1890.
40. J. J. STEVENSON, 1891.
41. H. S. WILLIAMS, 1892.
42. CHARLES D. WALCOTT, 1893.

*Section F.—Biology.*

31. W. H. DALL, 1882.
32. W. J. BEAL, 1883.
33. E. D. COPE, 1884.
34. T. J. BURRILL, 1885, in the absence of B. G. WILDER.
35. H. P. BOWDITCH, 1886.
36. W. G. FARLOW, 1887.
37. C. V. RILEY, 1888.
38. GEORGE L. GOODALE, 1889.
39. C. S. MINOT, 1890.
40. J. M. COULTER, 1891.
41. S. H. GAGE, 1892.

*Section F.—Zoölogy.*

42. HENRY F. OSBORN, 1893.

*Section G.—Microscopy.*

31. A. H. TUTTLE, 1882.
32. J. D. COX, 1883.
33. T. G. WORMLEY, 1884.
34. S. H. GAGE, 1885.

Section united with F in 1886.

*Section G.—Botany.*

42. CHARLES E. BESSEY, 1893.

*Section H.—Anthropology.*

31. ALEXANDER WINCHELL,* 1882.
32. OTIS T. MASON, 1883.
33. EDWARD S. MORSE, 1884.
34. J. OWEN DORSEY, 1885, in absence of W. H. DALL.
35. HORATIO HALE, 1886.
36. D. G. BRINTON, 1887.
37. CHARLES C. ABBOTT, 1888.
38. GARRICK MALLERY, 1889.
39. FRANK BAKER, 1890.
40. JOSEPH JASTROW, 1891.
41. W. H. HOLMES, 1892.
42. J. OWEN DORSEY, 1893.

*Section I.—Economic Science and Statistics.*

31. E. B. ELLIOTT,* 1882.
32. FRANKLIN B. HOUGH,* 1883.
33. JOHN EATON, 1884.
34. EDWARD ATKINSON, 1885.
35. JOSEPH CUMMINGS,* 1886.
36. H. E. ALVORD, 1887.
37. CHARLES W. SMILEY, 1888.
38. CHARLES S. HILL, 1889.
39. J. RICHARDS DODGE, 1890.
40. EDMUND J. JAMES, 1891.
41. LESTER F. WARD, 1892, in place of S. DANA HORTON, resigned.
42. WILLIAM H. BREWER, 1893.

## SECRETARIES.

*General Secretaries*, 1848–

1. WALTER R. JOHNSON,* 1848.
2. EBEN N. HORSFORD, 1849, in the absence of JEFFRIES WYMAN.
3. L. R. GIBBS, 1850, in absence of E. C. HERRICK.
4. E. C. HERRICK,* 1850.
5. WILLIAM B. ROGERS,* 1851, in absence of E. C. HERRICK.
6. WILLIAM B. ROGERS,* 1851.
7. S. ST. JOHN,* 1853, in absence of J. D. DANA.
8. J. LAWRENCE SMITH,* 1854.
9. WOLCOTT GIBBS, 1855.
10. B. A. GOULD, 1856.
11. JOHN LECONTE, 1857.
12. W. M. GILLESPIE,* 1858, in absence of WM. CHAUVENET.
13. WILLIAM CHAUVENET,* 1859.
14. JOSEPH LECONTE, 1860.
15. ELIAS LOOMIS, 1866, in the absence of W. P. TROWBRIDGE.
16. C. S LYMAN,* 1867.
17. SIMON NEWCOMB, 1868, in place of A. P. ROCKWELL, called home.
18. O. C. MARSH, 1869.
19. F. W. PUTNAM, 1870, in absence of C. F. HARTT.
20. F. W. PUTNAM, 1871.
21. EDWARD S. MORSE, 1872.
22. C. A. WHITE, 1873.
23. A. C. HAMLIN, 1874.
24. S. H. SCUDDER, 1875.
25. T. C. MENDENHALL, 1876.
26. AUG. R. GROTE, 1877.
27. H. C. BOLTON, 1878.
28. H. C. BOLTON, 1879, in the absence of GEORGE LITTLE.
29. J. K. REES, 1880.
30. C. V. RILEY, 1881.
31. WILLIAM SAUNDERS, 1882.
32. J. R. EASTMAN, 1883.
33. ALFRED SPRINGER, 1884.
34. C. S. MINOT, 1885.
35. S. G. WILLIAMS, 1886.
36. WILLIAM H. PETTEE, 1887.
37. JULIUS POHLMAN, 1888.
38. C. LEO MEES, 1889.
39. H. C. BOLTON, 1890.
40. H. W. WILEY, 1891.
41. A. W. BUTLER, 1892.
42. T. H. NORTON, 1893.

*Permanent Secretaries*, 1851–

5–7. SPENCER F. BAIRD,* 1851–3.
8–17. JOSEPH LOVERING,* 1854–68.
18. F. W. PUTNAM, 1869, in the absence of J. LOVERING.
19–21. JOSEPH LOVERING,* 1870–72.
22–23. F. W. PUTNAM, 1873–74.
24–28. F. W. PUTNAM, 1875–79.
29–33. F. W. PUTNAM, 1880–84.
34–38. F. W. PUTMAM, 1885–89.
39–43. F. W. PUTNAM, 1890–94.

*Assistant General Secretaries*, 1882-1887.

31. J. R. EASTMAN, 1882.
32. ALFRED SPRINGER, 1883.
33. C. S. MINOT, 1884, in the absence of E. S. HOLDEN.
34. S. G. WILLIAMS, 1885, in the absence of C. C. ABBOTT.
35. W. H. PETTEE, 1886.
36. J. C. ARTHUR, 1887.

*Secretaries of the Council*, 1888–

37. C. LEO MEES, 1888.
38. H. C. BOLTON, 1889.
39. H. W. WILEY, 1890.
40. A. W. BUTLER, 1891.
41. T. H. NORTON, 1892.
42. H. LEROY FAIRCHILD, 1893.

*Secretaries of Section A.—Mathematics, Physics and Chemistry*, 1875–81.

24. S. P. LANGLEY, 1875. / T. C. MENDENHALL, 1875.
25. A. W. WRIGHT, 1876.
26. H. C. BOLTON, 1877.
27. F. E. NIPHER, 1878.
28. J. K. REES, 1879.
29. H. B. MASON, 1880.
30. E. T. TAPPAN, 1881, in the absence of JOHN TROWBRIDGE.

*Secretaries of Section B.— Natural History*, 1875-81.

24. EDWARD S. MORSE, 1875.
25. ALBERT H. TUTTLE, 1876.
26. WILLIAM H. DALL, 1877.
27. GEORGE LITTLE. 1878.
28. WILLIAM H. DALL, 1879, in the absence of A. C. WETHERBY.
29. CHARLES V. RILEY, 1880.
30. WILLIAM SAUNDERS, 1881.

SECRETARIES OF SUBSECTIONS, 1875-81.

*Subsection of Chemistry.*

24. F. W. CLARKE, 1875.
25. H. C. BOLTON, 1876.
26. P. SCHWEITZER, 1877.
27. A. P. S. STUART, 1878.
28. W. R. NICHOLS,* 1879.
29. C. E. MUNROE, 1880.
30. ALFRED SPRINGER, 1881, in the absence of R. B. WARDER.

*Subsection of Entomology.*

30. B. P. MANN, 1881.

*Subsection of Anthropology.*

24. F. W. PUTNAM, 18·5.
25. OTIS T. MASON, 1876.
26, 27. United with ect onB.
28, 29, 30. J. G. HENDERSON, 1879-81.

*Subsection of Microscopy.*

25. E. W. MORLEY, 1876.
26. T. O. SOMMERS, JR., 1877.
27. G. J. ENGELMANN, 1878.
28, 29. A. B. HERVEY, 1879-1880.
30. W. H. SEAMAN, 1881, in the absence of S. P. SHARPLES.

SECRETARIES OF THE SECTIONS, 1882–

*Section A.—Mathematics and Astronomy.*

31. H. T. EDDY, 1882.
32. G. W. HOUGH, 1883, in the absence of W. W. JOHNSON.
33. G. W. HOUGH, 1884.
34. E. W. HYDE, 1885.
35. S. C. CHANDLER, 1886.
36. H. M. PAUL, 1887.
37. C. C. DOOLITTLE, 1888.
38. G. C. COMSTOCK, 1889.
39. W. W. BEMAN, 1890.
40. F. H. BIGELOW, 1891.
41. WINSLOW UPTON, 1892.
42. ANDREW W. PHILLIPS, 1893.

*Section B.—Physics.*

31. C. S. HASTINGS, 1882.
32. F. E. NIPHER, 1883, in the absence of C. K. WEAD.
33. N. D. C. HODGES, 1884.
34. B. F. THOMAS, 1885, in place of A. A. MICHELSON, resigned.
35. H. S. CARHART, 1886.
36. C. LEO MEES, 1887.
37. ALEX. MACFARLANE, 1888.
38. E. L. NICHOLS, 1889.
39. E. M. AVERY, 1890.
40. ALEX. MACFARLANE, 1891.
41. BROWN AYRES, 1892.
42. W. LECONTE STEVENS, 1893.

## SECRETARIES OF THE SECTIONS, CONTINUED.

*Section C.—Chemistry.*

31. ALFRED SPRINGER, 1882.
32. { J. W. LANGLEY, 1883. / W. MCMURTRIE, " }
33. H. CARMICHAEL, 1884, in the absence of R. B. WARDER.
34. F. P. DUNNINGTON, 1885.
35. W. MCMURTRIE, 1886.
36. C. S. MABERY, 1887.
37. W. L. DUDLEY, 1888.
38. EDWARD HART, 1889.
39. W. A. NOYES, 1890.
40. T. H. NORTON, 1891.
41. JAMES LEWIS HOWE, 1892.
42. J. U. NEF, 1893.

*Section D.—Mechanical Science and Engineering.*

31. J. BURKITT WEBB, 1882, in the absence of C. R. DUDLEY.
32. J. BURKITT WEBB, 1883, pro tempore.
33. J. BURKITT WEBB, 1884.
34. C. J. H. WOODBURY, 1885
35. WILLIAM KENT, 1886.
36. G. M. BOND, 1887.
37. ARTHUR BEARDSLEY, 1888.
38. W. B. WARNER, 1889.
39. THOMAS GRAY, 1890.
40. WILLIAM KENT, 1891.
41. O. H. LANDRETH, 1892.
42. D. S. JACOBUS, 1893.

*Section E.—Geology and Geography.*

31. H. S. WILLIAMS, 1882, in the absence of C. E. DUTTON.
32. A. A. JULIEN, 1883.
33. E. A. SMITH, 1884.
34. G. K. GILBERT, 1885, in the absence of H. C. LEWIS.
35. E. W. CLAYPOLE, 1886.
36. W. M. DAVIS, 1887, in the absence of T. B. COMSTOCK.
37. JOHN C. BRANNER, 1888.
38. JOHN C. BRANNER, 1889.
39. SAMUEL CALVIN, 1890.
40. W J MCGEE, 1891.
41. R. D. SALISBURY, 1892.
42. ROBERT T. HILL, 1893.

*Section F.—Biology.*

31. WILLIAM OSLER, 1882, in the absence of C. S. MINOT.
32. S. A. FORBES, 1883.
33. C. E. BESSEY, 1884.
34. J. A. LINTNER, 1885, in place of C. H. FERNALD, resigned.
35. J. C. ARTHUR, 1886.
36. J. H. COMSTOCK, 1887.
37. B. H. FERNOW, 1888.
38. A. W. BUTLER, 1889.
39. J. M. COULTER, 1890.
40. A. J. COOK, 1891.
41. B. D. HALSTED, 1892.

*Section F.—Zoölogy.*

42. L. O. HOWARD, 1893.

## SECRETARIES OF THE SECTIONS, CONTINUED.

*Section G.—Microscopy.*

31. ROBERT BROWN, JR., 1882.
32. CARL SEILER, 1883.
33. ROMYN HITCHCOCK, 1884.
34. W. H. WALMSLEY, 1885.

*Section G.—Botany.*

42. F. V. COVILLE, 1893.

*Section H.—Anthropology.*

31. OTIS T. MASON, 1882.
32. G. H. PERKINS, 1883.
33. G. H. PERKINS, 1884, in the absence of W. H. HOLMES.
34. ERMINNIE A. SMITH,* 1885.
35. A. W. BUTLER, 1886.
36. CHARLES C. ABBOTT, 1887, in absence of F. W. LANGDON.
37. FRANK BAKER, 1888.
38. W. M. BEAUCHAMP, 1889.
39. JOSEPH JASTROW, 1890.
40. W. H. HOLMES, 1891.
41. W. M. BEAUCHAMP, 1892, in place of S. CULIN, resigned.
42. WARREN K. MOOREHEAD, 1893.

*Section I.—Economic Science and Statistics.*

31. { FRANKLIN B. HOUGH,* 1882. J. RICHARDS DODGE, 1882. }
32. JOSEPH CUMMINGS,* 1883.
33. CHARLES W. SMILEY, 1884.
34. CHARLES W. SMILEY, 1885, in place of J. W. CHICKERING.
35. H. E. ALVORD, 1886.
36. W. R. LAZENBY, 1887.
37. CHARLES S. HILL, 1888.
38. J. RICHARDS DODGE, 1889.
39. B. E. FERNOW, 1890.
40. B. E. FERNOW, 1891.
41. HENRY FARQUHAR, 1892, in place of L. F. WARD made Vice-president.
42. NELLIE S. KEDZIE, 1893.

## TREASURERS.

1. JEFFRIES WYMAN*, 1848.
2. A. L. ELWYN,* 1849.
3. ST. J. RAVENEL,* 1850, in the absence of A. L. ELWYN.
4. A. L. ELWYN,* 1850.
5. SPENCER F. BAIRD,* 1851, in absence of A. L. ELWYN.

6–7. A. L. ELWYN,* 1851–1853.
8. J. L. LECONTE,* 1854, in absence of A. L. ELWYN.
9–19. A. L. ELWYN,* 1855–1870.
20–30. WILLIAM S. VAUX, 1871–1881.
32–42. WILLIAM LILLY, 1882–1893.

# COMMONWEALTH OF MASSACHUSETTS.

## IN THE YEAR ONE THOUSAND EIGHT HUNDRED AND SEVENTY-FOUR.

# AN ACT

## To Incorporate the "American Association for the Advancement of Science."

*Be it enacted by the Senate and House of Representatives, in General Court assembled, and by the authority of the same, as follows:*

Section 1. Joseph Henry of Washington, Benjamin Pierce of Cambridge, James D. Dana of New Haven, James Hall of Albany, Alexis Caswell of Providence, Stephen Alexander of Princeton, Isaac Lea of Philadelphia, F. A. P. Barnard of New York, John S. Newberry of Cleveland, B. A. Gould of Cambridge, T. Sterry Hunt of Boston, Asa Gray of Cambridge, J. Lawrence Smith of Louisville, Joseph Lovering of Cambridge and John LeConte of Philadelphia, their associates, the officers and members of the Association, known as the "American Association for the Advancement of Science," and their successors, are hereby made a corporation by the name of the "American Association for the Advancement of Science," for the purpose of receiving, purchasing, holding and conveying real and personal property, which it now is, or hereafter may be, possessed of, with all the powers and privileges, and subject to the restrictions, duties and liabilities set forth in the general laws which now or hereafter may be in force and applicable to such corporations.

Section 2. Said corporation may have and hold by purchase, grant, gift or otherwise, real estate not exceeding one hundred thousand dollars in value, and personal estate of the value of two hundred and fifty thousand dollars.

Section 3. Any two of the corporators above named are hereby authorized to call the first meeting of the said corporation in the month of August next ensuing, by notice thereof "by mail," to each member of the said Association.

Section 4. This act shall take effect upon its passage.

House of Representatives, March 10, 1874.
Passed to be enacted,
John F. Sanford, *Speaker*.

In Senate, March 17, 1874.
Passed to be enacted.
Geo. B. Loring, *President*.

March 19, 1874.
Approved,
W. B. Washburn.

Secretary's Department,
Boston, April 8, 1874.
A true copy, Attest:
David Pulsifer,
Deputy Secretary of the Commonwealth.

# CONSTITUTION

OF THE

# AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

Incorporated by Act of the General Court of the Commonwealth of Massachusetts.

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OBJECTS.

ARTICLE 1. The objects of the Association are, by periodical and migratory meetings, to promote intercourse between those who are cultivating science in different parts of America, to give a stronger and more general impulse and more systematic direction to scientific research, and to procure for the labors of scientific men increased facilities and a wider usefulness.

MEMBERS, FELLOWS, PATRONS AND HONORARY FELLOWS.

ART. 2. The Association shall consist of Members, Fellows, Patrons, Corresponding Members and Honorary Fellows.

ART. 3. Any person may become a Member of the Association upon recommendation in writing by two members or fellows, and election by the Council.

ART. 4. Fellows shall be elected by the Council from such of the members as are professionally engaged in science, or have by their labors aided in advancing science. The election of fellows shall be by ballot and a majority vote of the members of the Council at a designated meeting of the Council.

ART. 5. Any person paying to the Association the sum of one thousand dollars shall be classed as a Patron, and shall be entitled to all the privileges of a member and to all its publications.

ART. 6. Honorary Fellows of the Association, not exceeding three for each section, may be elected; the nominations to be made by the Council and approved by ballot in the respective sections before election by ballot in General Session. Honorary Fellows shall be entitled to all the privileges of Fellows and shall be exempt from all fees and assessments, and entitled to all publications of the Association issued after the date of their election. Corresponding Members shall consist of such scientists not residing in America as may be elected by the Council, and their number shall be limited to fifty. Corresponding Members shall be entitled to all the privileges of members and to the annual volumes of Proceedings published subsequent to their election.

ART. 7. The name of any member or fellow two years in arrears for annual dues shall be erased from the list of the Association, provided that two notices of indebtedness, at an interval of at least three months, shall have been given; and no such person shall be restored until he has paid his arrearages or has been reëlected. The Council shall have power to exclude from the Association any member or fellow, on satisfactory evidence that said member or fellow is an improper person to be connected with the Association, or has in the estimation of the Council made improper use of his membership or fellowship.

ART. 8. No member or fellow shall take part in the organization of, or hold office in, more than one section at any one meeting.

OFFICERS.

ART. 9. The Officers of the Association shall be elected by ballot in General Session from the fellows, and shall consist of a President, a Vice-President from each section, a Permanent Secretary, a General Secretary, a Secretary of the Council, a Treasurer, and a Secretary of each Section; these, with the exception of the Permanent Secretary, shall be elected at each meeting for the following one, and, with the exception of the Treasurer and the Permanent Secretary, shall not be reëligible for the next two meetings. The term of office of Permanent Secretary shall be five years.

ART. 10. The President, or, in his absence, the senior Vice President present, shall preside at all General Sessions of the Association and at all meetings of the Council. It shall also be the duty of the President to give an address at a General Session of the Association at the meeting following that over which he presided.

ART. 11. The Vice Presidents shall be chairmen of their respective Sections, and of their Sectional Committees, and it shall be part of their duty to give an address, each before his own section, at such time as the Council shall determine. The Vice Presidents may appoint temporary chairmen to preside over the sessions of their sections, but shall not delegate their other duties. The Vice Presidents shall have seniority in order of their continuous membership in the Association.

ART. 12. The General Secretary shall be the Secretary of all General Sessions of the Association, and shall keep a record of the business of these sessions. He shall receive the records from the Secretaries of the Sections, which, after examination, he shall transmit with his own records to the Permanent Secretary within two weeks after the adjournment of the meeting.

ART. 13. The Secretary of the Council shall keep the records of the Council. He shall give to the Secretary of each Section the titles of papers assigned to it by the Council. He shall receive proposals for membership and bring them before the Council.

ART. 14. The Permanent Secretary shall be the executive officer of the Association under the direction of the Council. He shall attend to all business not specially referred to committees nor otherwise constitutionally provided for. He shall keep an account of all business that he has transacted for the Association, and make annually a general report for publication in the annual volume of Proceedings. He shall attend to the printing and distribution of the annual volume of Proceedings, and all other printing ordered by the Association. He shall issue a circular of information to members and fellows at least three months before each meeting, and shall, in connection with the Local Committee, make all necessary arrangements for the meetings of the Association. He shall provide the Secretaries of the Association with such books and stationery as may be required for their records and business, and shall provide members and fellows with such blank forms as may be required for facilitating the business of the Association. He shall collect all assessments and admission fees, and notify members and fellows of their election, and of any arrearages. He shall receive, and bring before the Council, the titles and abstracts of papers proposed to be read before the Association. He shall keep an account of all receipts and expenditures of the Association, and report the same annually at the first meeting of the Council, and shall pay over to the Treasurer such unexpended funds as the Council may direct. He shall receive and hold in trust for the Association all books, pamphlets and manuscripts belonging to the Association, and allow the use of the same under the provisions of the Constitution and the orders of the Council. He shall receive all communications addressed to the Association during the interval between meetings, and properly attend to the same. He shall at each meeting report the names of fellows and members who have died since the preceding meeting. He shall be allowed a salary which shall be determined by the Council, and may employ one or more clerks at such compensation as may be agreed upon by the Council.

ART. 15. The Treasurer shall invest the funds received by him in such securities as may be directed by the Council. He shall annually present to the Council an account of the funds in his charge. No expenditure of the principal in the hands of the Treasurer shall be made without a unanimous vote of the Council, and no expenditure of the income received by the Treasurer shall be made without a two-thirds vote of the Council.

ART. 16. The Secretaries of the Sections shall keep the records of their respective sections, and, at the close of the meeting, give the same, including the records of subsections, to the General Secretary. They shall also be the Secretaries of the Sectional Committees. The Secretaries shall have seniority in order of their continuous membership in the Association.

ART. 17. In case of a vacancy in the office of the President, one of the Vice Presidents shall be elected by the Council as the President of the meeting. Vacancies in the offices of Vice President, Permanent Secretary, General Secretary, Secretary of the Council, and Treasurer, shall be filled by nomination of the Council and election by ballot in General Session. A vacancy in the office of Secretary of a Section shall be filled by nomination and election by ballot in the Section.

ART. 18. The Council shall consist of the past Presidents, and the Vice Presidents of the last meeting, together with the President, the Vice Presidents, the Permanent Secretary, the General Secretary, the Secretary of the Council, the Secretaries of the Sections, and the Treasurer of the current meeting, with the addition of one fellow elected from each Section by ballot on the first day of its meeting. The members present at any regularly called meeting of the Council, provided there are at least five, shall form a quorum for the transaction of business. The Council shall meet on the day preceding each annual meeting of the Association, and arrange the programme for the first day of the sessions. The time and place of this first meeting shall be designated by the Permanent Secretary. Unless otherwise agreed upon, regular meetings of the Council shall be held in the council room at 9 o'clock, A. M., on each day of the meeting of the Association. Special meetings of the Council may be called at any time by the President. The Council shall be the board of supervision of the Association, and no business shall be transacted by the Association that has not first been referred to, or originated with, the Council. The Council shall receive and assign papers to the respective sections; examine and, if necessary, exclude papers; decide which papers, discussions and other proceedings shall be published, and have the general direction of the publications of the Association; manage the financial affairs of the Association; arrange the business and programmes for General Sessions; suggest subjects for discussion, investigation or reports; elect members and fellows; and receive and act upon all invitations extended to the Association and report the same at a General Session of the Association. The Council shall receive all reports of Special Committees and decide upon them, and only such shall be read in General Session as the Council shall direct. The Council shall appoint at each meeting the following sub-committees who shall act, subject to appeal to the whole Council, until their successors are appointed at the following meeting: 1, on Papers and Reports; 2, on Members; 3, on Fellows.

ART. 19. The Nominating Committee shall consist of the Council, and one member or fellow elected by each of the Sections. It shall be the duty of this Committee to meet at the call of the President and nominate the general officers for the following meeting of the Association. It shall also be the duty of this Committee to recommend the time and place for the next meeting. The Vice President and Secretary of each Section shall be recommended to the Nominating Committee by a sub-committee consisting of the Vice President, Secretary, and three members or fellows elected by the Section.

### MEETINGS.

ART. 20. The Association shall hold a public meeting annually, for one week or longer, at such time and place as may be determined by vote of the Association, and the preliminary arrangements for each meeting shall be made by the Local Committee, in conjunction with the Permanent Secretary and such other persons as the Council may designate.

ART. 21. A General Session shall be held at 10 o'clock A. M., on the first day of the meeting, and at such other times as the Council may direct.

### SECTIONS AND SUBSECTIONS.

ART. 22. The Association shall be divided into Sections, namely:— A, *Mathematics and Astronomy*; B, *Physics*; C, *Chemistry, including its application to agriculture and the arts*; D, *Mechanical Science and Engineering*; E, *Geology and Geography*; F, *Zoölogy*; G, *Botany*; H, *Anthropology*; I, *Economic Science and Statistics*. The Council shall have power to consolidate any two or more Sections temporarily, and such consolidated Sections shall be presided over by the senior Vice President and Secretary of the Sections comprising it.

ART. 23. Immediately on the organization of a Section there shall be three fellows elected by ballot after open nomination, who, with the Vice President and Secretary and the Vice President and Secretary of the preceding meeting shall form its Sectional Committee. The Sectional Committees shall have power to fill vacancies in their own numbers. Meetings of the Sections shall not be held at the same time with a General Session.

ART. 24. The Sectional Committee of any Section may at its pleasure form one or more temporary Subsections, and may designate the officers thereof. The Secretary of a Subsection shall, at the close of the meeting, transmit his records to the Secretary of the Section.

ART. 25. A paper shall not be read in any Section or Subsection until it has been received from the Council and placed on the programme of the day by the Sectional Committee.

SECTIONAL COMMITTEES.

ART. 26. The Sectional Committees shall arrange and direct the business of their respective Sections. They shall prepare the daily programmes and give them to the Permanent Secretary for printing at the earliest moment practicable. No titles of papers shall be entered on the daily programmes except such as have passed the Council. No change shall be made in the programme for the day in a Section without the consent of the Sectional Committee. The Sectional Committees may refuse to place the title of any paper on the programme; but every such title, with the abstract of the paper or the paper itself, must be returned to the Council with the reasons why it was refused.

ART. 27. The Sectional Committees shall examine all papers and abstracts referred to the sections, and they shall not place on the programme any paper inconsistent with the character of the Association; and to this end they have power to call for any paper, the character of which may not be sufficiently understood from the abstract submitted.

PAPERS AND COMMUNICATIONS.

ART. 28. All members and fellows must forward to the Permanent Secretary, as early as possible, and when practicable before the convening of the Association, full titles of all the papers which they propose to present during the meeting, with a statement of the time that each will occupy in delivery, and also such abstracts of their contents as will give a general idea of their nature; and no title shall be referred by the Council to the Sectional Committee until an abstract of the paper or the paper itself has been received.

ART. 29. If the author of any paper be not ready at the time assigned, the title may be dropped to the bottom of the list.

ART. 30. Whenever practicable, the proceedings and discussions at General Sessions, Sections and Subsections shall be reported by professional reporters, but such reports shall not appear in print as the official reports of the Association unless revised by the Secretaries.

PRINTED PROCEEDINGS.

ART. 31. The Permanent Secretary shall have the Proceedings of each meeting printed in an octavo volume as soon after the meeting as possible, beginning one month after adjournment. Authors must prepare their papers or abstracts ready for the press, and these must be in the hands of the Secretaries of the Sections before the final adjournment of the meeting, otherwise only the titles will appear in the printed volume. The Council shall have power to order the printing of any paper by abstract or title only. Whenever practicable, proofs shall be forwarded to authors for revision. If any additions or substantial alterations are made by the author of a paper after its submission to the Secretary, the same shall be distinctly indicated. Illustrations must be provided for by the authors of the papers, or by a special appropriation from the Council. Immediately on publication of the volume, a copy shall be forwarded to every member and fellow of the Association who shall have paid the assessment for the meeting to which it relates, and it shall also be offered for sale by the Permanent Secretary at such price as may be determined by the Council. The Council shall also designate the institutions to which copies shall be distributed.

LOCAL COMMITTEE.

ART. 32. The Local Committee shall consist of persons interested in the objects of the Association and residing at or near the place of the proposed meeting. It is expected that the Local Committee, assisted by the officers of the Association, will make all essential arrangements for the meeting, and issue a circular giving necessary particulars, at least one month before the meeting.

LIBRARY OF THE ASSOCIATION.

ART. 33. All books and pamphlets received by the Association shall be in the charge of the Permanent Secretary, who shall have a list of the same printed and shall furnish a copy to any member or fellow on application. Members and fellows who have paid their assessments in full shall be allowed to call for books and pamphlets, which shall be delivered to them at their expense, on their giving a receipt agreeing to make good any loss or damage and to return the same free of expense to the Secretary at the time specified in the receipt given. All books and pamphlets in circulation must be returned at each meeting. Not more than five books, including volumes, parts of volumes, and pamphlets, shall be held at one time by any member or fellow. Any book may be withheld from circulation by order of the Council.

### Admission Fee and Assessments.

ART. 34. The admission fee for members shall be five dollars in addition to the annual assessment. On the election of any member as a fellow an additional fee of two dollars shall be paid.

ART. 35. The annual assessment for members and fellows shall be three dollars.

ART. 36. Any member or fellow who shall pay the sum of fifty dollars to the Association, at any one time, shall become a Life Member and as such shall be exempt from all further assessments, and shall be entitled to the Proceedings of the Association. All money thus received shall be invested as a permanent fund, the income of which, during the life of the member, shall form a part of the general fund of the Association; but, after his death, shall be used only to assist in original research, unless otherwise directed by unanimous vote of the Council.

ART. 37. All admission fees and assessments must be paid to the Permanent Secretary, who shall give proper receipts for the same.

### Accounts.

ART. 38. The accounts of the Permanent Secretary and of the Treasurer shall be audited annually, by Auditors appointed by the Council.

### Alterations of the Constitution.

ART. 39. No part of this Constitution shall be amended or annulled, without the concurrence of three-fourths of the members and fellows present in General Session, after notice given at a General Session of a preceding meeting of the Association.

# MEMBERS

OF THE

# AMERICAN ASSOCIATION

FOR THE

# ADVANCEMENT OF SCIENCE.[1]

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## PATRONS.[2]

THOMPSON, MRS. ELIZABETH, Stamford, Conn. (22).
LILLY, GEN. WILLIAM, Mauch Chunk, Carbon Co., Pa. (28). **F E**
HERRMAN, MRS. ESTHER, 59 West 56th St., New York, N. Y. (29).

## CORRESPONDING MEMBERS.[3]

Monselise, Prof. G., Via Principe Amedeo I, Milano, Italy (40). **C**
Warington, Robert, F.R.S., Rothamsted, Harpenden, England (40). **C**

## MEMBERS.[4]

Acker, Dr. Geo. N., 913 16th St., Washington, D. C. (40). **F**
Adriance, John S., 281 Broadway, New York, N. Y. (39). **C**
Agard, Dr. A. H., 1259 Alice St., Oakland, Alameda Co., Cal. (28).
Aitkin, Miss Clara I., 210 Madison St., Brooklyn, N. Y. (40). **H**
Aitkin, Miss Helen J., 210 Madison St., Brooklyn, N. Y. (40). **E H**

[1] The numbers in parentheses indicate the meeting at which the member was elected. The black letters at the end of line indicate the sections to which members elect to belong. The Constitution requires that the names of all members two or more years in arrears shall be omitted from the list, but their names will be restored on payment of arrearages. Members not in arrears are entitled to the annual volume of Proceedings bound in paper. *The payment of ten dollars at one time entitles a member to the subsequent volumes to which he may be entitled, bound in cloth, or by the payment of twenty dollars, to such volumes bound in half morocco.*

[2] Persons contributing one thousand dollars or more to the Association are classed as Patrons, and are entitled to the privileges of members and to the publications.

The names of Patrons are to remain permanently on the list.

[3] See ARTICLE VI of the Constitution.

[4] Any Member or Fellow may become a Life Member by the payment of fifty dollars. The income of the money derived from a Life Membership is used for the general purposes of the Association during the life of the member; afterwards it is to be used to aid in original research. Life Members are exempt from the annual assessment, and are entitled to the annual volume. The names of Life Members are printed in small capitals in the regular list of Members and Fellows.

Alden, Jno., Pacific Mills, Lawrence, Mass. (36).
Aldis, Owen F., 230 Monadnock Block, Chicago, Ill. (41). H
Allderdice, Wm. H., Ass't Eng. U. S. N., U. S. Naval Academy, Annapolis Md. (38). D
Allen, J. M., Hartford, Conn. (22). D
Allen, W. F., 24 Park Place, New York, N. Y. (36).
Allen, Walter S., New Bedford, Mass. (39). C I
Ammidown, Edward H., P. O. Box 2739, New York, N. Y. (37).
Anderson, Alexander D., Washington, D. C. (38).
Andrews, E. R., Rochester, N. Y. (41).
Angell, Geo. W. J., 44 Hudson St., New York, N. Y. (36).
Appleton, Rev. Edw. W., D.D., Ashbourne, Montgomery Co., Pa. (28).
Archambault, U. E., P. O. Box 1944, Montreal, P. Q., Can. (31).
Archbold, Dr. George, 121 and 123 Front St., New York, N. Y. (40).
Armstrong, Mrs. Lucius H., St. Nicholas, Duval Co., Fla. (30).
Atkinson, Jno. B., Earlington, Hopkins Co., Ky. (26). D
Auhagen, Wilhelm, Mt. Pleasant, 17th St. ext., Washington, D. C. (40).
Austin, H. W., No. 8 B St., S. E., Washington, D. C. (40). C
Avery, Robert Stanton, 320 A St., S. E., Washington, D. C. (40). A
AVERY, SAMUEL P., 4 E. 38th St., New York, N. Y. (36).
Ayer, Edward Everett, Room 12, The Rookery, Chicago, Ill. (37). H
Ayres, Horace B., Allamuchy, N. J. (40).

Babcock, Wm. H., Washington, D. C. (40).
Baker, Prof. Arthur Latham, 28 Strathallan Park, Rochester, N. Y. (41). A B
Baker, Charles S., Rochester, N. Y. (41). C D
Baker, Philip S., M.D., DePauw University, Greencastle, Ind. (39). C
Baker, Richard D., 112 So. 21st St., Philadelphia, Pa. (33). E C
Baker, Wm. G., 234 E. 15th St., New York, N. Y. (36).
Balderston, C. Canby, Westtown, Chester Co., Pa. (33). B
Baldwin, Miss Mary A., 28 Fulton St., Newark, N. J. (31). E
Baldwin, Mrs. G. H., 8 Madison Ave., Detroit, Mich. (34). H
Bancroft, Alonzo C., Elma, Erie Co., N. Y. (41).
Banes, Charles H., 1107 Market St., Philadelphia, Pa. (31). D
BANGS, LEMUEL BOLTON, M.D., 127 E. 34th St., New York, N. Y. (36).
Barber, D. H., Marion, Iowa (37).
Barclay, Robert, A.M., M.D., 3211 Lucas Ave., St. Louis, Mo. (30).
Bardeen, Francis L., M.D., Box 76, Onondaga Hill, N. Y. (32). C F B
BARGE, B. F., Mauch Chunk, Pa. (33).
Barker, Francis C., 200 D St., N. W., Washington, D. C. (40). E
Barker, Mrs. Martha M., 26 Eleventh St., Lowell, Mass. (31). E H
Barnes, Hon. Willis L., Charlestown, Ind. (40). A B
Barnum, Miss Charlotte C., 144 Humphrey St., New Haven, Conn. (36). A
Barrett, Fred. P., Gainesville, Wyoming Co., N. Y. (40). E
Barringer, Daniel M., Bullitt Building, Philadelphia, Pa. (40). C E
Barrows, Walter B., Dept. of Agric., Washington, D. C. (40). F

Bartley, Elias H., M.D., 21 Lafayette Ave., Brooklyn, N. Y. (33). C
Baskerville, Charles, Univ. of North Carolina, Chapel Hill, N. C. (41). C
Bass, Wm. H., 393 College Ave., Indianapolis, Ind. (39). D
Bastin, Edson Sewell, 3330 S. Park Ave., Chicago, Ill. (39).
Bates, Wm. W., Com. of Navigation, Washington, D. C. (38).
Bausch, Henry, P. O. Drawer 1033, Rochester, N. Y. (41).
Baxter, James N., care H. E. and C. Baxter, cor. Division and Bedford Sts., Brooklyn, N. Y. (36).
Beach, Spencer Ambrose, N. Y. Experiment Station, Geneva, N. Y. (41). F
Beall, Fielder M. M., Lieut. U. S. A., Auditorium Building, Chicago, Ill. (40).
Bean, B. A., Ass't Curator, Dept. of Fishes, National Museum, Washington, D. C. (40). F
Bean, Thos. E., Box 441, Galena, Ill. (28). F
Beaver, Daniel B. D., M.D., 150 North 6th St., Reading, Pa. (39).
Bechdolt, Adolphus F., Supt. City Schools, Mankato, Minn. (32). E B F
Becher, Franklin A., 406 Irving Place, Milwaukee, Wis. (41). I
Bedell, Frederick, 118 Elm St., Montclair, N. J. (41). B A
Bell, C. M., M.D., 320 Fifth Ave., New York, N. Y. (36).
Belt, R. V., 1314 10th St., N. W., Washington, D. C. (40).
Bemis, Edward W., Assoc. Prof. of Economics, Univ. of Chicago, Chicago, Ill. (41). I
Benner, Henry, N. W. University, Evanston, Ill. (40). A
Bennett, Charles M., Logansport, Ind. (39).
Benton, George W., High School, Indianapolis, Ind. (39). C
Berry, Daniel, M.D., Carmi, White Co., Ill. (41) B C E
Beveridge, David, Room 1141, The Rookery, Chicago, Ill. (38). I
Biddle, James G., 924 Chestnut St., Philadelphia, Pa. (39).
Bien, Julius, 140 Sixth Ave., New York, N. Y. (34). E H
Bigelow, Miss Clarissa, Kalamazoo, Mich. (39). A
Biggar, Hamilton F., M.D., 176 Euclid Ave., Cleveland, Ohio (40). B F
Bigney, Prof. A. J., Johns Hopkins Univ., Baltimore, Md. (40). F
Birdsall, Miss Louise W., 105 E. 37th St., New York, N. Y. (37). F E
Biscoe, Prof. Thomas Dwight, 404 Front St., Marietta, Ohio (41).
Bishop, Heber R., Mills Building, New York, N. Y. (36).
Blair, Mrs. Eliza N., 213 E. Capitol St., Washington, D. C. (40).
Blatchford, Eliphalet W., 375 No. La Salle St., Chicago, Ill. (17). F
Blatchley, Willis S., Terre Haute, Ind. (39). F
Bleile, Albert M., M.D., 342 S. Fourth St., Columbus, Ohio (37). F
Blish, W. G., Niles, Mich. (33). B D
Blount, Henry F., University Park, Washington, D. C. (32). I B
Blount, Mrs. Lucia E., Univ. Park, Washington, D. C. (34). H I
Boardman, William Dorr, 38 Kenilworth St., Roxbury, Mass. (38). E
Bogue, Rev. Horace P. V., Avon, N. Y. (41). H I
Bolley, Henry L., North Dakota Agric. Coll., Fargo, North Dakota (39). F
Booraem, J. V. V., 204 Lincoln Place, Brooklyn, N. Y. (36).

Booth, Miss Mary A., Longmeadow, Mass. (34). F I
Bourland, Addison M., M.D., Van Buren, Ark. (29). C E F
Boustead, W. E., Toronto, Ontario, Can. (38).
Bouton, Chas. L., M.S., 2909 Park Ave., St. Louis, Mo. (40). A D
Bowers, Miss Virginia K., 61 Taylor St., Newport, Ky. (27). F H B C
Bowman, Chas. G., Lt. U. S. N., Naval Acad., Annapolis, Md. (33).
Bowman, Walker, Blacksburg, Va. (39).
Boyer, Jerome L., Superintendent Chestnut Hill Iron Ore Co., Reading, Pa. (35). D
Brackenridge, Geo. W., San Antonio, Texas (41). I
Bradford, Chester, Patent Attorney, 16 & 18 Hubbard Block, Indianapolis, Ind. (39). D
Bradley, Charles S., Avon, N. Y. (40).
Brannon, M. A., Fort Wayne, Ind. (39). F
Bray, Prof. C. D., College Hill, Mass. (29). D B
Brayton, Miss Sarah H., M.D., Evanston, Ill. (33).
Breckenridge, J. C., Inspector General U. S. A., Inspector General's Office, War Dept., Washington, D. C. (40). E
Breckenridge, Prof. Lester P., Agricultural College, Mich. (41).
Brewer, Prof. Charles E., Wake Forest, N. C. (40).
Brice, Judge Albert G., 19 Camp St., New Orleans, La. (32). H
Brigham, Prof. Albert P., Hamilton, Madison Co., N. Y. (41).
Bristol, Wm. H., Stevens Institute, Hoboken, N. J. (36). A B D
Britton, Wiley, Pension Office, Washington, D. C. (40). F
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Bronson, Henry, 1198 Chapel Street, New Haven, Conn. (41). I
Brooks, Prof. Wm. P., Amherst, Mass. (38). C F
Broomall, Hon. John M., Media, Delaware Co., Pa. (23). A
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Brown, Prof. Charles Sumner, Rose Polytechnic Institute, Terre Haute, Ind. (39). D
Brown, C. Newton, Ohio State Univ., Columbus, Ohio (34).
Brown, Henry A., Saxonville, Mass. (38). I
Brown, Jonathan, 390 Broadway, Somerville, Mass. (29).
Brown, Paul Taylor, 103 Arch St., Philadelphia, Pa. (33). E
Brown, Samuel B., Morgantown, W. Va. (40). E
Brown, Prof. W. G., Lexington, Va. (40).
Brownell, Silas B., 71 Wall St., New York, N. Y. (36).
Brownell, Prof. Walter A., 905 University Avenue, Syracuse, N. Y. (30). E B C
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Buffum, Miss Fannie A., Linden, Mass. (29). E C
Burke, William, U. S. Patent Office, Washington, D. C. (28).
Burman, Rev. W. A., Winnepeg, Manitoba (38). F H
Burnett, Edgar A., Agricultural College, Mich. (41).

Burns, Prof. James A., Box 206, Atlanta, Ga. (32). C E I
Burr, Mrs. Laura E., Commercial Hotel, Lansing, Mich. (34). B
Burton, Prof. Alfred E., Mass. Inst. of Tech., Boston, Mass. (40). E
Burwell, Arthur W., 208 Superior St., Cleveland, Ohio (37).
Bush, Rev. Stephen, D.D., Waterford, N. Y. (19). E H
Byrd, Mary E., Smith College, Northampton, Mass. (34). A
Byrnes, Eugene A., Principal Examiner of Metallurgy and Chemist of the Patent Office, Washington, D. C. (40).

Cabot, John W., Box 440, Pottstown, Pa. (35). D
Calder, Edwin E., 15 Board of Trade Building, Providence, R. I. (29). C
Caldwell, Wm. H., State College, Centre Co., Pa. (37). I F
Calkins, Dr. Marshall, Springfield, Mass. (29).
Campbell, H. D., Ph.D., Lexington, Va. (40). F
Campbell, Jos. Addison, Queen Lane, Falls of Schuylkill P. O., Philadelphia, Pa. (33).
Campbell, Prof. John L., Crawfordsville, Ind. (39). B
Campbell, John T., Rockville, Ind. (39).
Campbell, Wm. A., M.D., Ann Arbor, Mich. (34). F B
Cannon, George L., jr., High School, Denver, Col. (39). F H
Cardeza, John M., M.D., Claymont, Del. (33). E
Carman, Prof. A. P., La Fayette, Ind. (39). B
Caron, C. K., Louisville, Ky. (30). E C
Carpenter, Geo. O., jr., care of St. Louis Lead and Oil Co., St. Louis, Mo. (29).
Carr, Oma, Ass't Chem. Dept. of Agric., Washington, D. C. (40).
CARTER, JAMES C., 277 Lexington Ave., New York, N. Y. (36).
Carter, James Madison G., M.D., Waukegan, Ill. (39). F
Carter, John E., Knox and Coulter Sts., Germantown, Pa. (33). B H
Carus, Paul, Ph.D., La Salle, Ill. (40).
Cary, Albert A., care Abendroth and Root M'f'g Co., cor. West and Noble Sts., Brooklyn, E. D., N. Y. (36). D
Catlin, Charles A., 133 Hope St., Providence, R. I. (33). C
Chadbourn, Erlon R., Lewiston, Me. (29).
Chamberlain, Prof. Joseph R., Raleigh, N. C. (41). F
Chandler, George V., Room 85, Patent Office, Washington, D. C. (40). B C
Chandler, John R., Ph.D., Fifth Ave. Hotel, New York, N. Y. (36). F H
Chaplin, Prof. Winfield S., care Washington Univ., St. Louis, Mo. (37). D A
Chapman, Mrs. Etta L., 1207 L St., N. W., Washington, D. C. (40).
Chapman, W. Albert, M. E., Yellville, Ark. (40). C
Charbonnier, Prof. L. H., University of Georgia, Athens, Ga. (26). A B D
Chase, Rev. E. B., Lake City, Minn. (37).
Chase, Mrs. Mariné J. (31). E F
Chase, R. Stuart, 53 Summer St., Haverhill, Mass. (18). F

Chatfield, A. F., Albany, N. Y. (29).
Cheshire, William W., 115 11th St., S. E., Washington, D. C. (40).
Chester, Commander Colby M., U. S. N., U. S. Naval Academy, Annapolis, Md. (28). E
Child, Wm. Addison, M.A., Ontario Rolling Mill Co., Swansea, Ont., Can. (38). C H D
Chipman, J. W., Indianapolis, Ind. (39). B
Christian, Ira W., Noblesville, Ind. (39).
Christie, James, Pencoyd, Pa. (33). D
Christy, Prof. Samuel B., Box 41, Berkeley, Cal. (35). D
Chrystie, Wm. F., Hastings-on-Hudson, New York, N. Y. (36).
Church, Royal Tyler, Turin, Lewis Co., N. Y. (38). D F
Clancy, Michael Albert, 1426 Corcoran St., Washington, D. C. (40). H
Clapp, Geo. H., 116 Water St., Pittsburgh, Pa. (33). H C
Clark, Alex. S., Westfield, N. J. (33).
Clark, Edward, 417 Fourth St., Washington, D. C. (40).
Clark, John S., 646 Washington St., Boston, Mass. (31). I B C
Clark, Oliver Durfee, 248 Schenck St., Brooklyn, N. Y. (41). F E
Clark, Thomas H., Clark Univ., Worcester, Mass. (40).
Clark, Tracy Earl, B. S., Pembroke, Genesee Co., N. Y. (41). F
Clark, Wm. Brewster, M.D., 50 E. 31st St., New York, N. Y. (33). F C
Clarke, Charles S., 130 Moss St., Peoria, Ill. (34).
Clarke, Francis Devereux, Principal Ark. Deaf Mute Inst., Little Rock, Arkansas (39). H
Clarke, Robert, Cincinnati, Ohio (30). H
Clarke, Sherman, 224 Alexander St., Rochester, N. Y. (41). C
Clendenin, Miss Ida May, Columbia, Boone Co., Mo. (40). F
COE, HENRY W., M.D., Hibernian Building, Portland, Oregon (32). H F
Coffin, Amory, Phœnixville, Chester Co., Pa. (31). D
Colt, J. Milner, Ph.D., Saint Paul's School, Concord, N. H. (33). B C E
COLBURN, RICHARD T., Elizabeth, N. J. (31). I F H
Cole, Aaron H., Greenwich, N. Y. (41). E F
Colie, Edw. M., East Orange, N. J. (30). E I
Collin, Rev. Henry P., Coldwater, Mich. (37). F
Collins, Prof. Jos. V., Miami Univ., Oxford, Ohio (37). A
Collins, William H., Haverford College, Haverford, Pa. (41). A
Colman, Henry, M.D., 7 Atlantic St., Lynn, Mass. (25). F
Colonna, B. A., U. S. C. and G. Survey, Washington, D. C. (37). E
Colton, Buel P., Normal, McLean Co., Ill. (34). F
Combs, George W., M.D., 30 E. Ohio St., Indianapolis, Ind. (39). F
Comstock, Dr. T. Griswold, 507 North 14th St., St. Louis, Mo. (29). F H
Conant, Prof. L. L., Polytechnic Inst., Worcester, Mass. (39). A
Condit, Chas. L., 1323 G St., Washington, D. C. (40).
Conklin, W. A., Director Central Park Menagerie, New York, N. Y. (29). F
Cook, Dr. Charles D., 133 Pacific St., Brooklyn, N. Y. (25).
Cook, Prof. Orator F., Clyde, N. Y. (40). F

Coon, Henry C., M.D., Alfred Centre, N. Y. (29). B C F
Cope, Thos. P., Awbury, Germantown, Pa. (33). I
Cordley, Arthur B., Washington, D. C. (40).
Costa, João Baptista Regueira (39). E
Cowles, Alfred H., 656 Prospect St., Cleveland, Ohio (37). B C
Coyrière, Mrs. E. M., 150 Fifth Ave., New York, N. Y. (36). H
Crafts, Robert H., 2329 So. 6th St., Minneapolis, Minn. (32). I B
Craig, John, Horticulturist, Experimental Farms, Ottawa, Ontario, Can. (41).
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ROGERS, WILLIAM B., Boston, Mass. (1). 1881. (Born Dec. 7, 1804. Died May 30, 1882.) **B E**

CHEVREUL, MICHEL EUGÈNE, Paris, France (35). 1886. (Born Aug. 31, 1786. Died April 9, 1889.) **C**

GENTH, DR. F. A., 3937 Locust St., Philadelphia, Pa. (24). 1888. **C E**

HALL, PROF. JAMES, Albany, N. Y. (1). 1890. **E F**

## FELLOWS.[2]

Abbe, Professor Cleveland, Meteorologist, Weather Bureau, Dept. of Agric., Washington, D. C. (16). 1874. **B A**

Abbe, Robert, 11 W. 50th St., New York, N. Y. (36). 1892.

Abbott, Dr. Chas. C., Trenton, N. J. (29). 1883. **F H**

Abert, S. Thayer, 1108 G St., N. W., Washington, D. C. (30). 1891. **A B D E I**

Alden, Prof. Geo. I., Worcester, Mass. (33). 1885. **D**

Alexander, John S., Texas Nat'l Bank, San Antonio, Texas (20). 1874. **B C D**

Allen, Joel A., American Museum of Natural History, 77th St. and 8th Ave., New York, N. Y. (18). 1875. **F**

Allen, Dr. T. F., 10 E. 36th St., New York, N. Y. (35). 1887. **F**

Alvord, Major Henry E., College Park, Prince George's Co., Md. (29). 1882. **I**

Alwood, Prof Wm. B., Agricultural and Mechanical College and Experiment Station, Blacksburg, Va. (39). 1891. **F**

Andrews, Prof. Launcelot W., Iowa City, Iowa (39). 1891. **C**

Anthony, Prof. Wm. A., Manchester, Conn. (28). 1880. **B**

Antisell, Thomas, M.D., 1311 Q St., N. W., Washington, D. C. (33). 1890. **C E**

Arey, Albert L., Free Academy, Rochester, N. Y. (35).

Arthur, J. C., La Fayette, Ind. (21). 1883. **F**

Ashmead, Wm. H., 1833 M St., N. W., Washington, D. C. (40). 1892. **F**

Atkinson, Edward, 31 Milk St., Boston, Mass. (29). 1881. **I D**

Atkinson, George F., Cornell Univ., Ithaca, N. Y. (39). 1892.

Atwater, Prof. W. O., Wesleyan Univ., Middletown, Conn. (29). 1882. **C**

Atwell, Charles B., 1038 Sherman St., Evanston, Ill. (36). 1890. **F**

Auchincloss, Wm. S., 209 Church St., Philadelphia, Pa. (29). 1886. **D A**

Avery, Elroy M., Ph.D., Woodland Hills Ave., Cleveland, Ohio (37). 1889. **B**

Ayres, Prof. Brown, Tulane Univ., New Orleans, La. (31). 1885. **B**

[1] See ARTICLE VI of the Constitution. [2] See ARTICLE IV of the Constitution.

*** The number in parenthesis indicates the meeting at which the member joined the Association; the date following is the year when made a Fellow; the black letters at end of line are those of the sections to which the Fellow belongs.

When the name is given in small capitals, it designates that the Fellow is also a Life Member, and is entitled to the Annual Volume of Proceedings.

Babcock, S. Moulton, Madison, Wis. (33). 1885. C
Bailey, E. H. S., Lawrence, Douglas Co., Kan. (25). 1889. C E
Bailey, Prof. Liberty H., Ithaca, N. Y. (34). 1887. F
Bailey, Prof. Loring W., University of Fredericton, N. B. (18). 1875.
Bailey, Prof. W. W., Brown University; residence, 6 Cushing St., Providence, R. I. (18). 1874. F
Baker, Frank, M.D., 1315 Corcoran St., Washington, D. C. (31). 1886. F H
Baker, Marcus, U. S. Geological Survey, Washington, D. C. (30). 1882. A
Baldwin, Judge Charles C., 1264 Euclid Ave., Cleveland, Ohio (37). 1891. H I
Ballard, Harlan H., 50 South St., Pittsfield, Mass. (31). 1891. E F
BARKER, PROF. G. F., 3909 Locust St., Philadelphia, Pa. (18). 1875. B C
Barnard, Edward E., Lick Observ., San José, Cal. (26). 1883. A
Barnes, Prof. Chas. R., Madison, Wis. (33). 1885. F
Bartlett, Prof. Edwin J., Dartmouth College, Hanover, N. H. (28). 1883. C
Bartlett, John R., Commander U. S. N., Lonsdale, R. I. (30). 1882. E B
Barus, Carl, Ph.D., U. S. Geol. Survey, Washington, D. C. (33). 1887. B
Bassett, Homer F., Waterbury, Conn. (23). 1874. F
Bates, Henry H., Ph.D., U. S. Patent Office, Washington, D. C. (33). 1887. B A C D
Battle, Herbert B., Ph.D., Director N. C. Agric. Exper. Station, Raleigh, N. C. (33). 1889. C
Bauer, Louis A., U. S. C. and G. Survey, Washington, D. C. (40). 1892. A
Baur, George, Univ. of Chicago, Chicago, Ill. (36). 1889.
Bausch, Edward, P. O. Drawer 1033, Rochester, N. Y. (26). 1883. A B C F
Beal, Prof. Wm. James, Agricultural College, Ingham Co., Mich. (17). 1880. F
Beardsley, Prof. Arthur, Swarthmore College, Swarthmore, Del. Co., Pa. (33). 1885. D
Beauchamp, Rev. Wm. M., Baldwinsville, N. Y. (34). 1886. H
Becker, Dr. Geo. F., U. S. Geol. Survey, Washington, D. C. (36). 1890. E
Bell, Dr. Alex. Graham, Scott Circle, 1331 Connecticut Ave., Washington, D. C. (26). 1879. B H I
Bell, Alex. Melville, 1525 35th St., Washington, D. C. (31). 1885. H
Bell, Robert, M.D., Ass't Director Geological Survey, Ottawa, Ontario, Can. (38). 1889. E F
Beman, Wooster W., 19 So. 5th St., Ann Arbor, Mich. (34). 1886. A
BENJAMIN, MARCUS, care D. Appleton & Co., 1 Bond St., New York, N. Y. (27). 1887. C
Benjamin, Rev. Raphael, M.A., 178 E. 70th St., New York, N. Y. (34). 1887. F A B D E H I

Bessey, Prof. Charles E., Univ. of Nebraska, Lincoln, Neb. (21). 1880. F

Bethune, Rev. C. J. S., Trinity College School, Pt. Hope, Ont., Can. (18). 1875. F

Beyer, Dr. Henry G., U. S. N., U. S. Naval Acad., Annapolis, Md. (31). 1884. F

Bickmore, Prof. Albert S., American Museum of Natural History, 8th Ave. and 77th St., Central Park, New York, N. Y. (17). 1880. H

Bigelow, Prof. Frank H., Naut. Almanac, Washington, D. C. (36). 1888. A

Billings, John S., Surgeon U. S. A., Surg. General's Office, Washington, D. C. (32). 1883. F H

Bixby, Wm. H., Cap't of Eng. U. S. A., Newport, R. I. (34). 1892. D

Blackham, George E., M.D., Dunkirk, N. Y. (25). 1883. F

Blake, Clarence J., M.D., 226 Marlborough St., Boston, Mass. (24). 1877. B F

Blake, Prof. Eli W., Brown Univ., Providence, R. I. (15). 1874. B

Blake, Francis, Auburndale, Mass. (23). 1874. B A

Blue, Archibald, Director of the Bureau of Mines, Toronto, Ontario, Can. (35). 1890. I

Boardman, Mrs. William D., 38 Kenilworth St., Roxbury, Mass. (28). 1885. E H

Boas, Dr. Franz, Clark Univ., Worcester, Mass. (36). 1888. H

Boerner, Chas. G., Vevay, Switzerland Co., Ind. (29). 1886. A B E

Bolton, Dr. H. Carrington, University Club, New York, N. Y. (17). 1875. C

Bond, Geo. M., care of The Pratt & Whitney Co., Hartford, Conn. (33). 1885. D

Bourke, John G., Capt. 3d Cavalry, U. S. A., War Dept., Washington, D. C. (33). 1885. H

Bouvé, Thos. T., Boston Soc. Nat. Hist., Boston, Mass. (1). 1875. E

Bowditch, Prof. H. P., Jamaica Plain, Mass. (28). 1880. F B H

Bowser, Prof. E. A., Rutgers College, New Brunswick, N. J. (28). 1881.

Brackett, Prof. C. F., College of New Jersey, Princeton, N. J. (19). 1875. B

Brackett, Richard N., Associate Prof. of Chemistry, Clemson Agric. College, Fort Hill, S. C. (37). C E

Bradford, Royal B., Commander U. S. N., care Navy Dept, Washington, D. C. (31). 1891. B D

Branner, John C., Leland Stanford Jr. Univ., Menlo Park, Cal. (34). 1886. E F

Brashear, Jno. A., Allegheny, Pa. (33). 1885. A B D

Brewer, Prof. Wm. H., New Haven, Conn. (20). 1875. E F I

Brewster, William, 61 Sparks St., Cambridge, Mass. (29). 1884. F

Brinton, D. G., M.D., Media, Pa. (33). 1885. H

Britton, N. L., Columbia College, New York, N. Y. (29). 1882. F E

Broadhead, Garland Carr, University, Columbia, Mo. (27). 1879. E

Brooks, Wm. R., Box 714, Geneva, N. Y. (35). 1886. A B D G

Brown, Robert, care of Yale College Observatory, New Haven, Conn. (11). 1874.

Brown, Mrs. Robert, New Haven, Conn. (17). 1874.

Brühl, Gustav, cor. John and Hopkins Sts., Cincinnati, Ohio (28). 1886. H

Brush, Charles F., Brush Electric Light Co., Cleveland, Ohio (35). 1886. B

BRUSH, PROF. GEORGE J., Yale College, New Haven, Conn. (4). 1874. C E

Buckhout, W. A., State College, Centre Co., Pa. (20). 1881. F

Burgess, Dr. Thomas J. W., Med. Sup't, Protestant Hospital for the Insane, Montreal, P.Q., Can. (38). 1889. F

Burr, Prof. William H., 151 W. 74th St., New York, N. Y. (31). 1883.

Burrill, Prof. T. J., Univ. of Illinois, Champaign, Ill. (29). 1882. F

Butler, A. W., Brookville, Franklin Co., Ind. (30). 1885. F H

Caldwell, Prof. Geo. C., Cornell University, Ithaca, N. Y. (23). 1875. C

Calvin, Prof. Samuel, State Univ. of Iowa, Iowa City, Iowa (37). 1889. E F

Campbell, Prof. Douglas H., Menlo Park, Cal. (34). 1888. F

Canby, William M., 1101 Delaware Avenue, Wilmington, Del. (17). 1878. F

Carhart, Prof. Henry S., University of Michigan, Ann Arbor, Mich. (29). 1881. B

Carpenter, Louis G., Agricultural College, Fort Collins, Col. (32). 1889. A B

Carpenter, Capt. W. L., U. S. A., Dunkirk, N. Y. (24). 1877. F E

Carpmael, Charles, Director of Magnetic Observatory, Toronto, Ontario, Can. (31). 1883. B

Carr, Lucien, Peabody Museum Archæology and Ethnology, Cambridge, Mass. (25). 1877. H

Casey, Thomas L., Room 79, Army Building, 39 Whitehall St., New York N. Y. (38). 1892. F

Chamberlain, Alexander F., Clark Univ., Worcester, Mass. (38). 1890. H

Chamberlin, T. C., 5041 Madison Ave., Chicago, Ill. (21). 1877. E B F H

Chandler, Prof. C. F., School of Mines, Columbia Coll., East 49th St. cor. 4th Ave., New York, N. Y. (19). 1875. C

Chandler, Prof. Charles Henry, Ripon, Wis. (28). 1883. A B

Chandler, Seth C., jr., 16 Craigie St., Cambridge, Mass. (29). 1882. A

Chandler, Prof. W. H., South Bethlehem, Pa. (19). 1874. C

Chanute, O., 413 E. Huron St., Chicago, Ill. (17). 1877. D I

Chester, Prof. Albert H., Rutgers College, New Brunswick, N. J. (29). 1882. C F

Chester, Prof. Fred'k D., Del. State Coll., Newark, Del. (33). 1887. E

Chickering, Prof. J. W., jr., Deaf Mute College, Washington, D. C. (22). 1877. F I

Christie, Alexander Smyth, U. S. C. and G. Survey, Washington, D. C. (39). 1891. A B D

Chute, Horatio N., Ann Arbor, Mich. (34). 1889. B C A

Clapp, Miss Cornelia M., Mt. Holyoke Seminary, South Hadley, Mass. (31). 1883. F

Clark, Alvan G., Cambridgeport, Mass. (28). 1880. A B

Clark, Prof. John E., 30 Trumbull St., New Haven, Conn. (17). 1875. A

Clark, Wm. Bullock, Ph.D., Johns Hopkins Univ., Baltimore, Md. (37). 1891. E

Clarke, Prof. F. W., U. S. Geological Survey, Washington, D. C. (18). 1874. C

Claypole, Prof. Edw. W., 603 Buchtel Ave., Akron, Ohio (30). 1882. E F

Clayton, H. Helm, Readville, Mass. (34). 1887. B

Cloud, John W., 974 Rookery, Chicago, Ill. (28). 1886. A B D

Coffin, Prof. Selden J., Lafayette College, Easton, Pa. (22). 1874. A I

Cogswell, W. B., Syracuse, N. Y. (33). 1891. D

Cole, Prof. Alfred D., Denison Univ., Granville, Ohio (39). 1891. B C

Collett, Prof. John, Indianapolis, Ind. (17). 1874. E

Collin, Prof. Alonzo, Cornell College, Mount Vernon, Iowa (21). 1891. B C

Collingwood, Francis, Elizabeth, N. J. (36). 1888. D

Colvin, Verplanck, Supt. N. Y. State Adirondack Survey, Albany, N. Y. (28). 1880. E

Comstock, Prof. Geo. C., Washburn Observ., Univ. of Wisconsin, Madison, Wis. (34). 1887. A

Comstock, J. Henry, 48 East Ave., Ithaca, N. Y. (28). 1882. F

Comstock, Milton L., 641 Academy St., Galesburg, Ill. (21). 1874. A

Comstock, Prof. Theo. B., Director School of Mines, Univ. of Arizona, Tucson, Arizona (24). 1877. D E B

Cook, Prof. A. J., Agricultural College, Mich. (24). 1880. F

Cook, Chas. Sumner, Evanston, Ill. (36). 1889. B

Cooley, Prof. Le Roy C., Vassar College, Poughkeepsie, N. Y. (19). 1880. B C

Cooley, Prof. Mortimer E., Univ. of Michigan, Ann Arbor, Mich. (33). 1885. D

Cope, Prof. Edward D., 2102 Pine St., Philadelphia, Pa. (17). 1875. F E

Corthell, Elmer L., "The Temple," Chicago, Ill. (34). 1886. D

Coulter, Prof. John M., Pres. Indiana Univ., Bloomington, Ind. (32). 1884. F

Coulter, Prof. Stanley, La Fayette, Ind. (35). 1890. F

Coville, Frederick V., Dept. of Agric., Washington, D. C. (35). 1890. F

Cox, Prof. Edward T., Gilsey House, New York, N. Y. (19). 1874. E

Cox, Hon. Jacob D., Gilman Ave., Mt. Auburn, Cincinnati, Ohio (30). 1881. F

Coxe, Eckley B., Drifton, Luzerne Co., Pa. (23). 1879. D E

Cragin, Francis W., Colorado College, Colorado Springs, Col. (29). 1890. F E H

Craighill, Col. Wm. P., 9 Pleasant St., Baltimore, Md. (37). 1892. D

Crampton, Chas. A., M.D., Office of Internal Revenue, Treasury Department, Washington, D.C. (36). 1887. C

Crandall, Prof. A. R., Lexington, Ky. (29). 1883. **E F**

Crawford, Prof. Morris B., Middletown, Conn. (30). 1889. **B**

Crosby, Prof. Wm. O., Boston Society of Natural History, Boston, Mass. (29). 1881. **E**

Cross, Prof. Chas. R., Mass. Institute Technology, Boston, Mass. (29). 1880. **B**

Crozier, A. A., Ann Arbor, Mich. (36). 1891. **F**

Culin, Stewart, 127 South Front St., Philadelphia, Pa. (33). 1890. **H**

Cummings, John, Cummingsville, Woburn, Mass. (18). 1890. **F**

Cushing, Henry Platt, 786 Prospect St., Cleveland, Ohio (33). 1888. **E**

Dall, William H., Smithsonian Institution, Washington, D. C. (18). 1874. **H F**

Dana, Edward Salisbury, New Haven, Conn. (23). 1875. **B E**

Dana, Prof. James D., New Haven, Conn. (1). 1875. **E**

Dancy, Frank B., A.B., Analytical and Consulting Chemist, Office and Laboratory, 133½ Fayetteville St., Raleigh, N. C. (33). 1890. **C**

Davidson, Prof. Geo., U. S. Coast and Geodetic Survey, San Francisco, Cal. (29). 1881. **A B D**

Davis, Wm. Morris, Cambridge, Mass. (33). 1885. **E B**

Dawson, Sir William, Principal McGill College, Montreal, Can. (10). 1875. **E**

Day, David F., Buffalo, N. Y. (35). 1887. **F**

Day, Fisk H., M.D., Wauwatosa, Wis. (20). 1874. **E H F**

Dean, George W., P. O. Box 92, Fall River, Mass. (15). 1874. **A**

Denton, Prof. James E., Stevens Institute, Hoboken, N. J. (36). 1888. **D B A**

Derby, Orville A., San Paulo, Brazil, S. A. (39). 1890.

Dewey, Fred P., Ph.B., 621 F St. N. W., Washington, D. C. (30). 1886. **C E**

Dimmock, George, P. O. Box 15, Canobie Lake, N. H. (22). 1874. **F**

Dodge, Charles R., 1336 Vermont Ave., Washington, D. C. (22). 1874.

Dodge, Prof. James A., University of Minnesota, Minneapolis, Minn. (29). 1884. **C E**

Dodge, J. Richards, Washington, D. C. (31). 1884. **I H**

Dolbear, A. Emerson, Tufts College, Mass. (20). 1880. **B**

Doolittle, Prof. C. L., South Bethlehem, Pa. (25). 1885. **A**

Dorsey, Rev. J. Owen, Box 79, Tacoma Park, D. C. (31). 1883. **H**

Douglass, Andrew E., 63 Pine St., New York, N. Y. (31). 1885. **H**

Dow, Capt. John M., 69 W. 71st St., New York, N. Y. (31). 1884. **F H**

DRAPER, DAN'L, Ph.D., Director N. Y. Meteorological Observatory, Central Park, 64th St., Fifth Avenue, New York, N. Y. (29). 1881. **B D F A**

Drown, Prof. Thos. M., Mass. Institute Technology, Boston, Mass. (29). 1881. **C**

DU BOIS, PROF. AUG. J., New Haven, Conn. (30). 1882. **A B D**

Du Bois, Patterson, Ass't Editor S.S.T., 1081 Walnut St., Philadelphia, Pa. (33). 1887. **H C I**

Dudley, Charles B., Altoona, Pa. (23). 1882. **C B D**

DUDLEY, WM. L., Prof. of Chemistry, Vanderbilt Univ., Nashville, Tenn. (28). 1881. **C**

Dudley, Prof. Wm. R., Leland Stanford, jr., Univ., Palo Alto, Cal. (29). 1883. **F**

Dumble, E. T., Austin, Texas (37). 1891. **E**

Dunham, Edw. K., 53 E. 30th St., New York, N. Y. (30). 1890.

Dunnington, Prof. F. P., University Station, Charlottesville, Va. (26). 1880. **C**

Durand, Prof. W. F., Ph.D., Agricultural College, Mich. (37). 1890. **B**

Dwight, Prof. William B., Vassar College, Poughkeepsie, N. Y. (30). 1882. **E F**

Eastman, Prof. J. R., U. S. Naval Observatory, Washington, D. C. (26). 1879. **A**

Eaton, Prof. D. G., 55 Pineapple St., Brooklyn, N. Y. (19). 1874. **B E**

Eaton, Prof. James R., Liberty, Mo. (29). 1885. **C B E**

Eddy, Prof. H. T., Rose Polytechnic Inst., Terre Haute, Ind. (24). 1875. **A B D**

Edison, Thos. A., Orange, N. J. (27). 1878. **B**

Egleston, Prof. Thomas, 35 W. Washington Square, New York, N. Y. (27). 1879. **C D E**

Eimbeck, William, U. S. C. and G. Survey, Washington, D. C. (17). 1874. **A B D**

Eldridge, Geo. H., care U. S. Geol. Survey, Washington, D. C. (37). 1890. **E**

Elkin, William L., Yale Coll. Observ., New Haven, Conn. (33). 1885. **A**

Ely, Theo. N., Sup't Motive Power, Penn. R. R., Altoona, Pa. (29). 1886.

Emerson, Prof. Benjamin K., Amherst, Mass. (19). 1877. **E F**

Emerson, Prof. C. F., Box 499, Hanover, N. H. (22). 1874. **B A**

Emery, Albert H., Stamford, Conn. (29). 1884. **D B**

Emery, Charles E., Bennett Building, New York, N. Y. (34). 1886. **D B A**

EMMONS, S. F., U. S. Geol. Survey, Washington, D. C. (26). 1879. **E**

Engelmann, George J., M.D., 3003 Locust St., St. Louis, Mo. (25). 1875. **F H**

Ernst, Carl W., Room 76, Post Office, Boston, Mass. (23). 1874. **I H**

Evermann, Prof. Barton W., U. S. Fish Commission, Washington, D. C. (39). 1891.

Eyerman, John, "Oakhurst," Easton, Pa. (33). 1889. **E C**

Fairbanks, Henry, Ph.D., St. Johnsbury, Vt. (14). 1874. **B D A**

Fairchild, Prof. H. L., University of Rochester, Rochester, N. Y. (28). 1883. **E F**

Fanning, John T., Consulting Eng., Kasota Block, Minneapolis, Minn. (29). 1885. **D**

Fargis, Rev. Geo. A., Georgetown College, Georgetown, D. C. (40). 1892.
Farlow, Dr. W. G., 29 Holyoke House, Cambridge, Mass. (20). 1875. **F**
Farmer, Moses G., Eliot, Me. (9). 1875.
Farquhar, Henry, Coast Survey Office, Washington, D. C. (33). 1886. **A I F B**
Fernald, Prof. M. C., State Agric. College, Orono, Me. (22). 1883. **B A**
Fernow, Bernhard E., Chief of Forestry Division, Dep't of Agriculture, Washington, D. C. (31). 1887. **F I**
Firmstone, F., Easton, Pa. (33). 1887. **D**
Fiske, Thos. S., A.M., Ph.D., Columbia College, New York, N. Y. (38). 1891. **A**
Fitch, Edward H., Jefferson, Ashtabula Co., Ohio (11). 1874. **I E**
Fletcher, Miss Alice C., care Peabody Museum, Cambridge, Mass. (29). 1883. **H**
Fletcher, James, Dominion Entomologist, Experimental Farm, Ottawa, Ontario, Can. (31). 1883. **F**
Fletcher, Dr. Robert, Army Medical Museum, Washington, D. C. (29). 1881. **F H**
Flint, Albert S., Washburn Observ., Madison, Wis. (30). 1887. **A**
Flint, James M., Surgeon U. S. N., Smithsonian Institution, Washington, D. C. (28). 1882. **F**
Foote, Dr. A. E., 4116 Elm Ave., Philadelphia, Pa. (21). 1874. **E C**
Forbes, Prof. S. A., Univ. of Illinois, Champaign, Ill. (27). 1879. **F**
Fox, Oscar C., U. S. Patent Office, Washington, D. C. (36). 1891. **B D**
Foye, Prof. J. C., Lawrence Univ., Appleton, Wis. (29). 1884. **C B**
Franklin, William S., Ames, Iowa (36). 1892.
FRAZER, DR. PERSIFOR, Drexel Building, Room 1042, Philadelphia, Pa. (24). 1879. **E C**
Frazier, Prof. B. W., The Lehigh University, So. Bethlehem, Pa. (24). 1882. **E C**
Frear, Wm., State College, Centre Co., Pa. (33). 1886. **C**
Freer, Prof. Paul C., Ann Arbor, Mich. (39). 1891. **C**
French, Prof. Thomas, jr., Ridgeway Ave., Avondale, Cincinnati, Ohio (30). 1883. **B**
Frisby, Prof. Edgar, U. S. N. Observ., Washington, D. C. (28). 1880. **A**
Frost, Edwin Brant, Hanover, N. H. (38). 1890. **A B**
Fuller, Andrew S., Ridgewood, Bergen Co., N. J. (24). 1882. **F**
Fuller, Prof. Homer T., Polytechnic Inst., Worcester, Mass. (35). 1891. **C E**

Gaffield, Thomas, 54 Allen St., Boston, Mass. (29). 1889. **C B**
Gage, Simon Henry, Ithaca, N. Y. (28). 1881. **F**
Galbraith, Prof. John, Toronto, Ontario, Can. (38). 1889.
Galloway, B. T., Dep't of Agriculture, Washington, D. C. (37). 1890. **F**
Gannett, Henry, U. S. Geological Survey, Washington, D. C. (33). 1884. **E I A**

Gardiner, Dr. Edward G., Massachusetts Institute Technology, Boston, Mass. (29). 1890. **F**

Garland, Rev. Dr. L. C., Chancellor Vanderbilt University, Nashville, Tenn. (25). 1877. **B**

Garman, Samuel, Museum Comparative Zoology, Cambridge, Mass. (20). 1874. **F E**

Gatschet, Dr. Albert S., Box 333, Washington, D. C. (30). 1882. **H**

Gibbs, Prof. J. Willard, New Haven, Conn. (33). 1885. **B**

Gilbert, G. K., U. S. Geological Survey, Washington, D. C. (18). 1874. **E**

Gill, Prof. Theo., Smithsonian Inst., Washington, D. C. (17). 1874. **F**

Gilman, Daniel C., President Johns Hopkins University, Baltimore, Md. (10). 1875. **E H**

Goessman, Prof. C. A., Mass. Agricultural College, Amherst, Mass. (18). 1875. **C**

Goff, E. S., 1113 University Ave., Madison, Wis. (35). 1889.

Gold, Theodore S., West Cornwall, Conn. (4). 1887. **B C**

Goldschmidt, S. A., Ph.D., 43 Sedgwick St., Brooklyn, N. Y. (24). 1880. **C E B**

Goldsmith, Edw., 658 No. 10th St., Philadelphia, Pa. (29). 1892. **C B**

Gooch, Frank A., Yale College, New Haven, Conn. (25). 1880. **C**

Goodale, Prof. G. L., Botanic Gardens, Cambridge, Mass. (18). 1875.

Goode, G. Brown, Curator Nat'l Museum, Washington, D. C. (22). 1874.

Goodfellow, Edward, Ass't U. S. Coast and Geodetic Survey, Washington, D. C. (24). 1879. **A H**

Gould, Dr. B. A., Cambridge, Mass. (2). 1875. **A B**

Grant, Mrs. Mary J., Brookfield, Conn. (23). 1874. **A**

Gratacap, L. P., Ph.B., 77th St. and 8th Ave., New York, N. Y. (27). 1884. **C E F**

Gray, Elisha, Sc.D., Highland Park, Ill. (32). 1883. **B**

Gray, Prof. Thomas, Terre Haute, Ind. (38). 1889.

Green, Arthur L., La Fayette, Ind. (33). 1888. **C**

Green, Traill, M.D., Easton, Pa. (1). 1874. **C F**

Griffith, Ezra H., 5656 Washington Ave., Chicago, Ill. (39). 1892. **B F**

Grimes, J. Stanley, No. 1, Tribune Building, Chicago, Ill. (17). 1874. **E H**

Grinnell, George Bird, 40 Park Row, New York, N. Y. (25). 1885. **F E**

Gulley, Prof. Frank A., College Station, Texas (30). 1883.

Hague, Arnold, U. S. Geol. Survey, Washington, D. C. (26). 1879.

Haines, Reuben, Haines and Chew St., Germantown, Philadelphia, Pa. (27). 1889. **C B**

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Hall, Asaph, Jr., Univ. of Mich, Ann Arbor, Mich. (38). 1890. **A**
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Hall, Prof. Edwin H., 5 Avon St., Cambridge, Mass. (29). 1881. **B**
Hall, Prof. Lyman B., Haverford College, Haverford, Pa. (31). 1884. **C**
Hallowell, Miss Susan M., Wellesley Coll., Wellesley, Mass. (33). 1890. **F**
Halsted, Byron D., New Jersey Agricultural Experiment Station, New Brunswick, N. J. (29). 1883. **F**
Hambach, Dr. G., 1319 Lami St., St. Louis, Mo. (26). 1891. **F E**
Hamlin, Dr. A. C., Bangor, Me. (10). 1874. **C E H**
HANAMAN, C. E., Troy, N. Y. (19). 1883. **F**
Hardy, Prof. A. S., Dartmouth College, Hanover, N. H. (28). 1888. **A**
Hargitt, Prof. Charles W., Syracuse, N. Y. (38). 1891. **F**
HARKNESS, PROF. WILLIAM, U. S. N. Observatory, Washington, D. C. (26). 1878. **A B C D**
Harrington, H. H., College Station, Texas (35). 1889. **C**
Harris, Uriah R., Lieutenant U. S. N., U. S. Naval Acad., Annapolis, Md. (34). 1886. **A**
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HASTINGS, C. S., Sheffield Scientific School of Yale College, New Haven, Conn. (25). 1878. **B**
Haupt, Prof. Lewis M., University of Pennsylvania, Philadelphia, Pa. (32). 1885. **I D E**
Haworth, Prof. Erasmus, Pennsylvania College, Oskaloosa, Iowa (37). 1890. **E**
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Haynes, Henry W., 239 Beacon St., Boston, Mass. (28). 1884. **H**
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Hendricks, J. E., 1400 Court Ave., Des Moines, Iowa (29). 1885. **A**
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Hervey, Rev. A. B., President St. Lawrence University, Canton, N.Y. (22). 1879. **F**
Hicks, Prof. Lewis E., State University, Lincoln, Neb. (31). 1885. **E F**
Hilgard, Prof. E. W., University of California, Berkeley, Cal. (11). 1874. **C E B**
Hill, Robert Thomas, U. S. Geol. Survey, Washington, D. C. (36). 1889. **E**
Himes, Prof. Charles F., Carlisle, Pa. (29). 1882. **B C**
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Hirschfelder, Chas. A., Vice Consul U. S. A., Toronto, Ontario, Can. (33). 1887. **H**

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Holm, Theodor, U. S., Natl. Museum, Washington, D. C. (40). 1892. **F**

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Hough, Prof. G. W., Northwestern Univ., Evanston, Ill. (15). 1874. **A**

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Jenks, Prof. J. W. P., Middleborough, Mass. (2). 1874. B
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Johnson, John B., Washington Univ., St. Louis, Mo. (33). 1886. D
Johnson, Lawrence C., U. S. Geol. Survey, Gainesville, Fla. (33). 1887.
Johnson, Otis C., 52 Thayer St., Ann Arbor, Mich. (34). 1886. C
Jordan, Prof. David S., Palo Alto, Menlo Park P. O., Cal. (31). 1883. F
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Kedzie, Prof. Robert C., Agricultural College, Mich. (29). 1881. C
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LeConte, Prof. Joseph, Univ. of Cal., Berkeley, Cal. (29). 1881. **E F**

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Leverett, Frank, Denmark, Iowa (37). 1891. **E**

Libbey, Prof. William, jr., Princeton, N. J. (29). 1887. **E F**

LILLY, GEN. WM., Mauch Chunk, Carbon Co., Pa. (28). 1882. (Patron) **F E**

Lindahl, Josua, Ph.D., State Geologist, Springfield, Ill. (40). 1892. **F E**

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Locy, Prof. Wm. A., Lake Forest, Ill. (34). 1890. **F**

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Lord, Prof. Nat. W., State Univ., Columbus, Ohio (29). 1881. **C**

Loud, Prof. Frank H., 1203 N. Tejon St., Colorado Springs, Col. (29). **A B**

Loudon, Prof. James, Toronto, Ontario, Can. (25). 1881. **B A**

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Low, Seth, Pres. Columbia Coll., New York, N. Y. (29). 1890.
Lupton, Prof. N. T., Auburn, Lee Co., Ala. (17). 1874. C
Lyon, Dr. Henry, 34 Monument Sq., Charlestown, Mass. (18). 1874.

McAdie, Alexander George, U. S. Weather Bureau, Washington, D. C. (40). 1892. B
McBride, Prof. Thomas H., Iowa City, Iowa (38). 1890. F
McCauley, Capt. C. A. H., Ass't Q. M., U. S. A., 321 Michigan Ave., Chicago, Ill. (29). 1881.
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McGregory, Prof. J. F., Colgate Univ., Hamilton, N. Y. (35). 1892.
McGuire, Joseph D., Ellicott City, Md. (30). 1891. H
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McNeill, Malcolm, Lake Forest, Ill. (32). 1885. A
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Macfarlane, Prof. A., Univ. of Texas, Austin, Texas (34). 1886. B A
Macloskie, Prof. George, College of New Jersey, Princeton, N. J. (25). 1882. F
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Mallery, Col. Garrick, U. S. Army, Bureau of Ethnology, Washington, D. C. (26). 1879. H
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MARSH, PROF. O. C., Yale College, New Haven, Conn. (15). 1874. F H
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Martin, Prof. Daniel S., 236 West 4th St., New York, N. Y. (23). 1879. E F
Martin, Prof. H. Newell, Johns Hopkins University, Baltimore, Md. (27). 1880. F H
Martin, Miss Lillie J., Girls' High School, San Francisco, Cal. (32). 1886. F C
Martin, Prof. Wm. J., Davidson College, N. C. (31). 1884. C E
Martindale, Isaac C., Camden, N. J. (26). 1890. F
Marvin, C. F., Signal Office, Washington, D. C. (39). 1892. B
Mason, Prof. Otis T., Nat'l Museum, Washington, D. C. (25). 1877. H

Mason, Dr. William P., Prof. Rensselaer Polytechnic Inst., Troy, N. Y. (31). 1886. C

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Maxwell, Rev. Geo. M., Wyoming, Hamilton Co., Ohio (30). 1886. H E

Mayer, Prof. A. M., Stevens Inst. of Technology, Hoboken, N. J. (19). 1874.

Meehan, Thomas, Germantown, Pa. (17). 1875. F

Mees, Prof. Carl Leo, Rose Polytechnic Inst., Terre Haute, Ind. (24). 1876. B C

Mendenhall, Prof. T. C., U. S. C. and G. Survey, Washington, D. C. (20). 1874. B

Menocal, Aniclto G., C.E., U. S. N., Navy Yard, Washington, D. C. (36). 1888. D

Merrill, Frederick J. H., Ph.B., Ass't Director, New York State Museum, Albany, N. Y. (35). 1887. E

Merriman, C. C., 1910 Surf St., Lake View, Chicago, Ill. (29). 1880. F

Merriman, Prof. Mansfield, So. Bethlehem, Pa. (32). 1885. A D

Merritt, Ernest, Ithaca, N. Y. (33). 1890.

Metz, Charles L., M.D., Madisonville, Hamilton Co., Ohio (30). 1885. H

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Miles, Prof. Manly, Lansing, Mich. (29). 1890. F

Mills, Wesley, Montreal, P. Q., Can. (31). 1886. F H

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Minot, Dr. Charles Sedgwick, Harvard Medical School, Back Bay, Boston, Mass. (28). 1880. F

Minot, Francis, M.D., 65 Marlborough St., Boston, Mass. (29). 1884.

Mixter, Prof. Wm. G., New Haven, Conn. (30). 1882. C

Moody, Robert O., Fair Haven Heights, New Haven, Conn. (35). 1892. F

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Moore, Eliakim Hastings, 5311 Washington Ave., Chicago, Ill. (39). 1891. A

Moore, Prof. J. W., M.D., Lafayette College, Easton, Pa. (22). 1874. B D A

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Morse, Prof. E. S., Salem, Mass. (18). 1874. F H

Morton, H., Stevens Institute Technology, Hoboken, N. J. (18). 1875. B C

Moser, Lieut. Jeff. F., U. S. N., Slatington, Lehigh Co., Pa. (28). 1889. E

Moses, Prof. Thomas F., Urbana University, Urbana, Ohio (25). 1883. H F
Munroe, Prof. C. E., Columbian Univ., Washington. D. C. 1874. C
Murdoch, John, Rock, Plymouth Co., Mass. (29). 1886. F H
Murtfeldt, Miss Mary E., Kirkwood, Mo. (27). 1881. F
Myers, John A., Agric. Exper. Station, Morgantown, W. Va. (30). 1889. C

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Nason, Prof. H. B., Rensselaer Polytechnic Institute, Troy, N. Y. (13). 1874. C E
Nef, J. U., Clark Univ., Worcester, Mass. (39). 1891. C
Nelson, Prof. A. B., Centre College, Danville, Ky. (30). 1882. A B D
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Newberry, Prof. Spencer Baird, Ithaca, N. Y. (33). 1887. C
Newcomb, Prof. S., Navy Dep't, Washington, D. C. (13). 1874. A B
Newton, Hubert A., New Haven, Conn. (6). 1874. A
Nichols, E. L., Ph.D., Cornell Univ., Ithaca, N. Y. (28). 1881. B C
Nicholson, Prof. H. H., Box 675, Lincoln, Neb. (36). 1888.
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Nipher, Prof. F. E., Washington Univ., St. Louis, Mo. (24). 1876. B
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Norton, Lewis M., Ph.D., Mass. Institute of Technology, Boston, Mass. (29). 1884. C
NORTON, PROF. THOMAS H., Univ. of Cincinnati, Cincinnati, Ohio (35). 1887. C
Novy, Dr. Frederick G., University of Mich., Ann Arbor, Mich. (36). 1889. C
Noyes, Prof. Wm. A., Rose Polytechnic Inst., Terre Haute, Ind. (32). 1885. C
Nuttall, Mrs. Zelia, care Peabody Museum, Cambridge, Mass. (35). 1887. H
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Orton, Prof. Edward, President Ohio Agricultural and Mechanical College, Columbus, Ohio (19). 1875. E
Osborn, Henry F., Columbia College, New York, N. Y. (29). 1883.

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Preston, E. D., Ass't U. S. Coast and Geodetic Survey, Washington, D. C. (37). 1889. A E
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Prosser, Charles S., Prof. of Geology, Washburn College, Topeka, Kan. (33). 1891. E F
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Rice, John M., Northborough, Mass. (25). 1881. A D
Rice, Prof. Wm. North, Wesleyan University, Middletown, Conn. (18). 1874. E F
Richards, Prof. Charles B., 137 Edwards St., New Haven, Conn. (33). 1885. D
Richards, Edgar, 113 E. 30 St., New York, N. Y. (31). 1886. C
Richards, Prof. Robert H., Mass. Inst. Tech., Back Bay, Boston, Mass. (22). 1875. D
Richards, Mrs. Robert H., Prof. Mass. Inst. of Tech., Back Bay, Boston, Mass. (23). 1878. C

Richardson, Clifford, Office of the Engineer Commissioner, Washington, D. C. (30). 1884. C

Ricketts, Prof. Palmer C., 17 1st St., Troy, N. Y. (33). 1887. D A

Ricketts, Prof. Pierre de Peyster, 104 John St., New York, N. Y. (26). 1880. C D E

RILEY, PROF. C. V., U. S. Entomologist, U. S. National Museum, Washington, D. C. (17). 1874. F H I

Risteen, Allen D., Hartford, Conn. (38). 1890. A B D

Ritchie, E. S., Newton Highlands, Mass. (10). 1877. B

Roberts, Prof. Isaac P., Ithaca, N. Y. (33). 1886. I

Robinson, Prof. Franklin C., Bowdoin College, Brunswick, Me. (29). 1889. C D

Robinson, Prof. S. W., 1353 Highland St., Columbus, Ohio (30). 1883. D B A

Rockwell, Gen. Alfred P., Manchester, Mass. (10). 1882. E

Rockwell, Chas. H., Box 293, Tarrytown, N. Y. (28). 1883. A D

Rockwood, Prof. Charles G., jr., College of New Jersey, Princeton, N. J. (20). 1874. A E B D

Rogers, Fairman, Newport, R. I. (11). 1874.

Rogers, Prof. W. A., Colby Univ., Waterville, Me. (15). 1875. A B D

Rominger, Dr. Carl, Ann Arbor, Mich. (21). 1879. E

Rood, Prof. O. N., Columbia College, New York, N. Y. (14). 1875. B

Ross, Waldo O., 1 Chestnut St., Boston, Mass. (29). 1882.

Rowland, Prof. Henry A., Baltimore, Md. (29). 1880. B

Runkle, Prof. J. D., Mass. Institute of Technology, Boston, Mass. (2). 1875. A D

Rusby, Henry H., M.D., College of Pharmacy, 211 E. 23d St., New York, N. Y. (36). 1890. F

Russell, I. C., U. S. Geological Survey, Washington, D. C. (25). 1882. E

Ryan, Harris J., Cornell Univ., Ithaca, N. Y. (38). 1890. B

Sadtler, Sam'l P., Ph.D., 1042 Drexel Building, Philadelphia, Pa. (22). 1875. C

Saegmuller, G. N., 132 Maryland Ave., S. W., Washington, D. C. (38). 1891. A B

Safford, Dr. James M., Nashville, Tenn. (6). 1875. E C F

Safford, Prof. Truman H., Williamstown, Mass. (41). 1892. A

Salisbury, Prof. R. D., Chicago Univ., Chicago, Ill. (37). 1890. B E

Salmon, Daniel E., Dep't of Agric., Washington, D. C. (31). 1885. F

Saunders, William, Director Canadian Experimental Farms, Ottawa, Ontario, Can. (17). 1874. F

SCHAEBERLE, J. M., Astronomer in the Lick Observatory, San José, Cal. (34). 1886. A

Schanck, Prof. J. Stillwell, Princeton, New Jersey (4). 1882. C B H

Schott, Charles A., U. S. Coast and Geodetic Survey Office, Washington, D. C. (8). 1874. A

Schweinitz, Dr. E. A. de, Dep't of Agriculture, Washington, D. C. (36). 1889. **C**

Schweitzer, Prof. Paul, State University of Missouri, Columbia, Mo. (24). 1877. **C B**

Scovell, M. A., Director Kentucky Agricultural Experiment Station, Lexington, Ky. (35). 1887.

Scribner, F. Lamson, Director Tenn. Agricultural Exper. Station, Knoxville, Tenn. (34). 1887. **F**

SCUDDER, SAMUEL H., Cambridge, Mass. (13). 1874. **F**

Seaman, W. H., Chemist, 1424 11th St. N. W., Washington, D. C. (23). 1874. **C F**

Searle, Prof. Geo. M., Catholic Univ., Washington, D. C. (39). 1891. **A**

See, Horace, 1 Broadway, New York, N. Y. (34). 1886. **D**

Seiler, Carl, M.D., 1846 Spruce St., Philadelphia, Pa. (29). 1882. **F B**

Seymour, Arthur Bliss, Cambridge, Mass. (36). 1890. **F**

Seymour, William P., M.D., 105 Third St., Troy, N. Y. (19). 1888. **H**

Sharples, Stephen P., 13 Broad St., Boston, Mass. (29). 1884. **C**

Shimer, Porter W., E.M., Easton, Pa. (38). 1889. **C**

Shufeldt, Dr. R. W., Smithsonian Institution, Washington, D. C. (40). 1892. **F**

Shutt, Frank T., M.A., F.E.C., F.C.S., Chief Chemist Canadian Experimental Farm, Ottawa, Ontario, Can. (38). 1889. **C**

Sias, Solomon, M.D., Schoharie, Schoharie Co., N. Y. (10). 1874.

Sigsbee, Chas. D., Comd'r U. S. N., U. S. Naval Acad., Annapolis, Md. (28). 1882. **D E**

Silliman, Prof. Justus M., Lafayette Coll., Easton, Pa. (19). 1874. **D E**

Simonds, Prof. Frederic W., Univ. of Texas, Austin, Texas (25). 1888 **E F**

Skinner, Joseph J., Massachusetts Inst. Technology, Boston, Mass. (28). 1880. **B**

Smiley, Charles W., U. S. Fish Commission, Washington, D. C. (28). 1883. **I**

Smith, Alex., Ph.D., Wabash College, Crawfordsville, Ind. (40). 1892. **C**

Smith, Prof. Chas. J., 35 Adelbert St., Cleveland, Ohio (32). 1885. **A B**

Smith, Prof. Edgar F., Univ. of Penn., Philadelphia, Pa. (33). 1891. **C**

Smith, Edwin, Ass't U. S. Coast and Geodetic Survey, Washington, D. C. (30). 1882. **A B**

Smith, Prof. Erastus G., Beloit College, Beloit, Wis. (34). 1887. **C**

Smith, Erwin F., Dep't of Agric., Washington, D. C. (34). 1890. **F**

Smith, Prof. Eugene A., University, Ala. (20). 1877. **E C**

Smith, John B., Professor of Entomology, Rutgers College, New Brunswick, N. J. (32). 1884. **F**

SMITH, QUINTIUS C., M.D., No. 617 Colo. St., Austin, Texas (26). 1881. **F**

Smith, Dr. Theobald, Bureau of Animal Industry, U. S. Dep't of Agric., Washington, D. C. (35). 1887. **F**

Smock, Prof. John Conover, Trenton, N. J. (23). 1879. E
Snow, Prof. F. H., Lawrence, Kan. (29). 1881. F E
Snow, Prof. Benj. W., Bloomington, Ind. (35). 1889. B
Snyder, Henry, B.Sc., Miami Univ., Oxford, Ohio (30). 1888. B C
Snyder, Prof. Monroe B., High School Observatory, Philadelphia, Pa. (24). 1882. A B
Soule, R. H., Roanoke, Va. (33). 1886. D
Spalding, Volney M., Ann Arbor, Mich. (34). 1886. F
Spencer, Guilford L., Department Agriculture, Washington, D. C. (36). 1889. C D
Spencer, Prof. J. William, 7 Church St., Atlanta, Ga. (28). 1882. E
Spencer, John W., Paxton, Sullivan Co., Ind. (20). 1874.
Springer, Dr. Alfred, Box 621, Cincinnati, Ohio (24). 1880. C
Staley, Cady, LL.D., Pres. Case School of Applied Sciences, Cleveland, Ohio (37). 1888. D
Starr, Frederick, Ph.D., Prof. Univ. of Chicago, Chicago, Ill. (36). 1892. H E
Stearns, R. E. C., care Smithsonian Institution, Washington, D. C. (18). 1874. F
Stedman, Prof. John M., Trinity Univ., Durham, N. C. (40). 1892. F
Steere, Prof. Jos. B., Ann Arbor, Mich. (34). 1890. F H
STEPHENS, W. HUDSON, Lowville, N. Y. (18). 1874. E H
Sternberg, Col. George M., Surgeon U. S. A., Army Building, 39 Whitehall St., New York, N. Y. (24). 1880. F
Stevens, Prof. W. LeConte, Rensselaer Polytechnic Inst., Troy, N. Y. (29). 1882. B A C
Stevenson, Prof. John J., Univ. of New York, New York, N. Y. (36). 1888.
Stockwell, John N., 1008 Case Avenue, Cleveland, Ohio (18). 1875. A
Stoddard, Prof. John T., Smith College, Northampton, Mass. (35). 1889. B C
Stokes, Henry Newlin, Ph.D., Univ. of Chicago, Chicago, Ill. (38). 1891. C E
Stone, Ormond, Director Leander McCormick Observatory, University of Virginia, Va. (24). 1876. A
Stone, Prof. Winthrop E., Purdue Univ., La Fayette, Ind. (39). 1891. C
Story, Prof. Wm. E., Clark Univ., Worcester, Mass. (29). 1881. A
Stowell, Prof. T. B., Potsdam, N. Y. (28). 1885. F
Stringham, Prof. Irving, Univ. of Cal., Berkeley, Cal. (33). 1885. A
Stuart, Prof. A. P. S., Lincoln, Nebraska (21). 1874. C
Sturgis, Wm. C., 384 Whitney Ave., New Haven, Conn. (40). 1892. F
Sturtevant, E. Lewis, M.D., So. Framingham, Mass. (29). 1882. F
Swift, Lewis, Ph.D., Warner Observatory, Rochester, N. Y. (29). 1882. A
Swingle, W. T., Eustis, Florida (40). 1892. F

Tainter, Charles Sumner, 1843 S, cor. 19 St., Washington, D. C. (29). 1881. B D A
Taylor, H. C., Commander U. S. N. (30). 1889.

Taylor, Thos., M.D., Department of Agriculture, Washington, D. C. (29). 1885. **F C**

Taylor, William B., Smithsonian Institution, Washington, D. C. (29). 1881. **B A**

Thomas, Benj. F., Ph.D., State Univ., Columbus, Ohio (29). 1882. **B A**

Thomson, Elihu, Thomson-Houston Electric Co., Lynn, Mass. (37). 1888. **B**

Thomson, Wm., M.D., 1426 Walnut St., Philadelphia, Pa. (33). 1885. **B**

Thruston, Gates Phillips, Nashville, Tenn. (38). 1890. **H**

Thurston, Prof. R. H., Sibley College, Cornell University, Ithaca, N. Y. (23). 1875. **D**

Thwing, Charles B., Northwestern Univ., Evanston, Ill. (38). 1892. **B**

Tittmann, Otto H., U. S. Coast and Geodetic Survey Office, Washington, D. C. (24). 1888. **A**

Todd, Prof. David P., Director Lawrence Observatory, Amherst College, Amherst, Mass. (27). 1881. **A B D**

Todd, Prof. James E., Tabor, Fremont Co., Iowa (22). 1886. **E F**

Towne, Henry R., Pres. Yale and Towne Manufacturing Co., Stamford, Conn. (33). 1888. **D B**

Townshend, Prof. N. S., Ohio State Univ., Columbus, Ohio (17). 1881. **F H**

Tracy, Sam'l M., Agricultural College, Miss. (27). 1881. **F**

Traphagen, Frank W., Ph.D., Prof. of Chem., The College of Montana, Deer Lodge City, Montana (35). 1889. **C F E**

Trelease, Dr. Wm., Director Missouri Botanical Gardens, St. Louis, Mo. (39). 1891 **F**

Trimble, Prof. Henry, 145 No. 10 St., Philadelphia, Pa. (34). 1889. **C**

True, Fred W., U. S. National Museum, Washington, D. C. (28). 1882. **F**

Trumbull, Dr. J. Hammond, Hartford, Conn. (29). 1882. **H**

Tucker, Willis G., M.D., Albany Med. Coll., Albany, N. Y. (29). 1888. **C**

TUCKERMAN, ALFRED, Ph.D., 342 W. 57th St., New York, N. Y. (39). 1891. **C**

Tuttle, Prof. Albert H., Univ. of Virginia, Charlottesville, Va. (17). 1874. **F**

Twitchell, E., 559 W. Seventh St., Cincinnati, Ohio (39). 1891. **C**

Uhler, Philip R., 254 W. Hoffman St., Baltimore, Md. (19). 1874. **F E**

Underwood, Prof. Lucien M., De Pauw Univ., Greencastle, Ind. (33). 1885. **F**

Upham, Warren, 36 Newbury St., Somerville, Mass. (25). 1880. **E**

Upton, Winslow, Brown Univ., Providence, R. I. (29). 1883. **A**

Van der Weyde, P. H., M.D., 236 Duffield St., Brooklyn, N. Y. (17). 1874. **B**

Van Dyck, Prof. Francis Cuyler, New Brunswick, N. J. (28). 1882. **B C F**

Van Hise, Charles R., Univ. of Wisconsin, Madison, Wis. (37). 1890.

Van Vleck, Prof. John M., Wesleyan Univ., Middletown, Conn. (23). 1875. **A**

Vasey, George, M.D., Dep't of Agric., Washington, D. C. (32). 1889. F
Venable, Prof. F. P., Chapel Hill, N. C. (39). 1891. C
Very, Samuel W., Lieut. Comdr. U. S. N., Robeson St., Jamaica Plain, Mass. (28). 1886. A B
Vining, Edward P., 816 Olive St., St. Louis, Mo. (32). 1887. H
Vogdes, A. W., Fort Canby, Pacific Co., Washington (32). 1885. E F

Wachsmuth, Charles, 111 Marietta St., Burlington, Iowa (30). 1884. E F
Wadsworth, Prof. M. Edward, Ph.D., Director of the Michigan Mining School, State Geologist of Michigan, Houghton, Mich. (23). 1874. E
Walcott, Charles D., U. S. Geological Survey, Washington, D. C. (25). 1882. E F
Waldo, Prof., Clarence A., Greencastle, Ind. (37). 1889. A
Wallace, Wm., Ansonia, Conn. (28). 1882.
WALLER, E., School of Mines, Columbia College, New York, N. Y. (23). 1874.
Walmsley, W. H., 1016 Chestnut St., Philadelphia, Pa. (28). 1883. F
Wanner, Atreus, York, York Co., Pa. (36). 1890. H
Ward, Prof. Henry A., Rochester, N. Y. (13). 1875. F E H
Ward, Lester F., U. S. Geological Survey, Washington, D. C. (26). 1879. E F
Ward, Dr. R. H., 53 Fourth St., Troy, N. Y. (17). 1874. F B
Ward, Wm. E., Port Chester, N. Y. (36). 1889. D
Warder, Prof. Robert B., Howard Univ., Washington, D. C. (19). 1881. C B
Warner, Prof. A. G., District Offices, Washington, D. C. (38). 1892. I
WARNER, JAMES D., 199 Baltic St., Brooklyn, N. Y. (18). 1874. A B
Warner, Worcester R., 887 Case Ave., Cleveland, Ohio (33). 1888. A B D
Warren, Cyrus M., Brookline, Mass. (29). 1882. C
Warren, Dr. Joseph W., Bryn Mawr College, Bryn Mawr, Pa. (31). 1886. F
Warren, Prof. S. Edward, Newton, Mass. (17). 1875. A–I
WATSON, PROF. WM., 107 Marlborough St., Boston, Mass. (12). 1884. A
Webb, Prof. J. Burkitt, Stevens Inst., Hoboken, N. J. (31). 1883. D B A
Weber, Prof. Henry A., Ohio State Univ., Columbus, Ohio (35). 1888. F
Webster, F. M., Wooster, Ohio (35). 1890.
Webster, Prof. N. B., Grove House, Vineland, N. J. (7). 1874. B C E
Weed, Clarence M., Hanover, N. H. (38). 1890.
Weston, Edward, 645 High St., Newark, N. J. (33). 1887. B C D
Wheatland, Dr. Henry, President Essex Inst., Salem, Mass. (1). 1874.
Wheeler, Prof. C. Gilbert, 143 Lake St., Chicago, Ill. (18). 1883. C E
Wheeler, Orlando B., Office Mo. River Com., 1515 Lucas Place, St. Louis, Mo. (24). 1882. A D
White, Prof. C. A., Le Droit Park, Washington, D. C. (17). 1875. E F
White, Prof. H. C., Univ. of Georgia, Athens, Ga. (29). 1885. C
WHITE, PROF. I. C., Univ. of W. Va., Morgantown, W. Va. (25). 1882. E
Whiteaves, J. F., Geol. Survey, Ottawa, Ontario, Can. (31). 1887. E F

Whitfield, R. P., American Museum Natural History, 77th St. & 8th Avenue, New York, N. Y. (18). 1874. E F H
Whiting, Miss Sarah F., Wellesley College, Wellesley, Mass. (31). 1883. B A
Whitman, Prof. Frank P., Adelbert College, Cleveland, Ohio (33). 1885. A B
Wilbur, A. B., Middletown, N. Y. (23). 1874.
Wiley, Prof. Harvey W., Dep't of Agric., Washington, D.C. (21). 1874. C
Williams, Benezette, 171 La Salle St., Chicago, Ill. (33). 1887. D
Williams, Charles H., M.D., C. B. and Q. Gen. Office, Adams St., Chicago, Ill. (22). 1874.
Williams, Geo. Huntington. Johns Hopkins Univ., Baltimore, Md. (33). 1886. E
Williams, Prof. Henry Shaler, Yale College, New Haven, Conn. (18). 1882. E F
Williams, Prof. Henry W., 15 Arlington St., Boston, Mass. (11). 1874. H F
Williams, Prof. S. G., Cornell Univ., Ithaca, N. Y. (33). 1885. E
Willis, Bailey, U. S. Geol. Survey, Washington, D. C. (36). 1890.
Willmott, Arthur B., 6 Little's Block, Cambridge, Mass. (38). 1890.
Willson, Prof. Frederick N., Princeton, N. J. (33). 1887. A D
Willson, Robert W., Cambridge, Mass. (30). 1890. B A
Wilson, Herbert M., U. S. Geol. Survey, Washington, D. C. (40). 1892. D E
Wilson, Joseph M., Room 1036, Drexel Building, Philadelphia, Pa. (33). 1886. D
Wilson, Thomas, U. S. Nat'l Museum, Washington, D. C. (36). 1888. H
Wilson, Prof. William Powell, Dept. of Biology, Univ. of Pa., Philadelphia, Pa. (38). 1889. F
Winchell, Horace V., 1306 S. E. 7th St., Minneapolis, Minn. (34). 1890. E C
Winchell, Prof. N. H., Univ. of Minnesota, Minneapolis, Minn. (19). 1874. E H
Wing, Henry H., 3 Reservoir Ave., Ithaca, N. Y. (38). 1890.
Winlock, Wm. C., Smithsonian Institution, Washington, D. C. (33). 1885. A B
Winslow, Arthur, State Geologist, Jefferson City, Mo. (37). 1889. E
Withers, Prof. W. A., Agric. and Mechanical College, Raleigh, N. C. (33). 1891. C
Witthaus, Dr. R. A., 410 E. 26th St., New York, N. Y. (35). 1890.
Wood, Prof. De Volson, Hoboken, N. J. (29). 1881.
Woodbury, C. J. H., 31 Milk St., Boston, Mass. (29). 1884. D
Woodward, Prof. Calvin M., 1761 Missouri Ave., St. Louis, Mo. (32). 1884. D A I
Woodward, R. S., care U. S. C. & G. Survey, Washington, D. C. (33). 1885. A B D
Wormley, T. G., Univ. of Pennsylvania, Philadelphia, Pa. (20). 1878.

Worthen, W. E., 68 Bleeker St., New York, N. Y. (36). 1888. **D**
Wrampelmeier, Theo. J., Berkeley, Cal. (34). 1887. **C**
Wright, Prof. Albert A., Oberlin College, Oberlin, Ohio (24). 1880. **E F**
Wright, Prof. Arthur W., Yale Coll., New Haven, Conn. (14). 1874. **A B**
Wright, Rev. Geo. F., Oberlin College, Oberlin, Ohio (29). 1882. **E**
Wright, Prof. Thos. W., Union College, Schenectady, N. Y. (36). 1889.
Würtele, Rev. Louis C., Acton Vale, P. Q., Can. (11). 1875. **E**

Youmans, Wm. Jay, M.D., Popular Science Monthly, 1–5 Bond St., New York, N. Y. (28). 1889. **F C**
Young, A. V. E., Northwestern Univ., Evanston, Ill. (33). 1886. **C B**
Young, C. A., Prof. of Astronomy, College of New Jersey, Princeton, N. J. (18). 1874. **A B D**

Zalinski, E. L., Capt. 5th Artillery, U. S. A., Fort Hamilton, New York Harbor, N. Y. (36). 1891. **D**
Ziwet, Alexander, 14 So. State St., Ann Arbor, Mich. (38). 1890. **A**

[786 FELLOWS.]

SUMMARY.—PATRONS, 3; CORRESPONDING MEMBERS, 2; MEMBERS, 1246; HONORARY FELLOWS, 2; FELLOWS, 784.

NOV. 1, 1892, TOTAL NUMBER OF MEMBERS OF THE ASSOCIATION, 2037.

# DECEASED MEMBERS.

[Unless by special vote of the Council, the names of those only who are members of the Association at the *time of their decease* will be included in this list. Information of the date and place of birth and death, to fill blanks in this list, is requested by the Permanent Secretary.]

Abbe, George W., New York, N. Y. (23). Died Sept. 25, 1879.

Abert, John James, Washington, D. C. (1). Born in Shepherdstown, Va., Sept. 17, 1788. Died in Washington, D. C., Sept. 27, 1863.

Adams, Charles Baker, Amherst, Mass. (1). Born in Dorchester, Mass., Jan. 11, 1814. Died in St. Thomas, W. I., Jan. 19, 1853.

Adams, Edwin F., Charlestown, Mass. (18).

Adams, Samuel, Jacksonville, Ill. (18). Born Dec. 19, 1806. Died April 29, 1877.

Agassiz, Louis, Cambridge, Mass. (1). Born in Parish of Motier, Switzerland, May 28, 1807. Died in Cambridge, Mass., Dec. 14, 1873.

Ainsworth, J. G., Barry, Mass. (14).

Alexander, Stephen, Princeton, N. J. (1). Born Sept. 1, 1806. Died June 25, 1883.

Allen, Thomas, St. Louis, Mo. (27). Died April 8, 1882.

Allen, Zachariah, Providence, R. I. (1). Born in Providence, R. I., Sept. 15, 1795. Died March 17, 1882.

Allston, Robert Francis Withers, Georgetown, S. C. (3). Born in All Saints Parish, S. C., April 21, 1801. Died near Georgetown, S. C., April 7, 1864.

Alvord, Benjamin, Washington, D. C. (17). Born in Rutland, Vt., Aug. 18, 1813. Died Oct. 16, 1884.

Ames, M. P., Springfield, Mass. (1). Born in 1803. Died April 23, 1847.

Andrews, Ebenezer Baldwin, Lancaster, Ohio (7). Born in Danbury, Conn., April 29, 1821. Died in Lancaster, Ohio, Aug. 14, 1880.

Anthony, Charles H., Albany, N. Y. (6). Died in 1874.

Appleton, Nathan, Boston, Mass. (1). Born in New Ipswich, N. H., Oct. 6, 1779. Died July 14, 1861.

Armstrong, John W., Fredonia, N. Y. (24).

Ashburner, Charles A., Pittsburgh, Pa. (31). Died Dec. 24, 1889.

Ashburner, Wm., San Francisco, Cal. (29). Born in Stockbridge, Mass., March, 1831. Died in San Francisco, Cal., April 20, 1887.

Atwater, Mrs. S. T., Chicago, Ill. (17). Born Aug. 8, 1812. Died April 11, 1878.

Aufrecht, Louis, Cincinnati, Ohio (30).

Baba, Tatui, New York, N. Y. (36).

Babbitt, Miss Franc E., Coldwater, Mich. (32). Died near Coldwater, Mich., July 6, 1891, aged 67.

Bache, Alexander Dallas, Washington, D. C. (1). Born in Philadelphia, Pa., July 19, 1806. Died at Newport, R. I., Feb. 17, 1867.

Bache, Franklin, Philadelphia, Pa. (1). Born in Philadelphia, Pa., Oct. 25, 1792. Died March 19, 1864.

Bailey, Jacob Whitman, West Point, N. Y. (1). Born in Auburn, Mass., April 29, 1811. Died in West Point, N. Y., Feb. 26, 1857.

Baird, Spencer Fullerton, Washington, D. C. (1). Born in Reading, Pa., Feb. 3, 1823. Died in Wood's Holl, Mass., Aug. 19, 1887.

Bardwell, F. W., Lawrence, Kan. (13). Died in 1878.

Barnard, F. A. P., New York, N. Y. (7). Born in Sheffield, Mass., May 5, 1809. Died in New York, April 27, 1889.

Barnard, John Gross, New York, N. Y. (14). Born in Sheffield, Mass., May 19, 1815. Died in Detroit, Mich., May 14, 1882.

Barrett, Dwight H., Baltimore, Md. (36). Died in March, 1889.

Barrett, Moses, Milwaukee, Wis. (21). Died in 1873.

Barry, Redmond, Melbourne, Australia (25).

Bassett, Daniel A., Los Angeles, Cal. (29). Born Dec. 8, 1819. Died May 26, 1887.

Bassnett, Thomas, Jacksonville, Fla. (8). Born 1807. Died in Jacksonville, Fla., Feb. 16, 1886.

Batchelder, John Montgomery, Cambridge, Mass. (8). Born in New Ipswich, N. H. Oct. 13, 1811. Died in Cambridge, July 3, 1892.

Bayne, Herbert Andrew, Kingston, Ont., Can. (29). Born in Londonderry, Nova Scotia, Aug. 16, 1846. Died in Pictou, Can., Sept. 16, 1886.

Beach, J. Watson, Hartford, Conn. (23). Born Dec. 28, 1823. Died Mar. 16, 1887.

Beck, C. F., Philadelphia, Pa. (1).

Beck, Lewis Caleb, New Brunswick, N. J. (1). Born in Schenectady, N. Y., Oct. 4, 1798. Died April 20, 1853.

Beck, Theodoric Romeyn, Albany, N. Y. (1). Born in Schenectady, N. Y., Aug. 11, 1791. Died in Utica, N. Y., Nov. 19, 1855.

Beckwith, Henry C., Coleman's Station, N. Y. (29). Died July 12, 1885.

Belfrage, G. W., Clifton, Texas (29). Died Dec. 7, 1882.

Belknap, William B., Louisville, Ky. (29).

Bell, Samuel N., Manchester, N. H. (7). Born in Chester, N. H., March 25, 1829. Died in Manchester, N. H., Feb. 8, 1889.

Belt, Thomas, London, Eng. (27). Died Sept. 8, 1878.

Benedict, George Wyllys, Burlington, Vt. (16). Born Jan. 11, 1796. Died Sept. 23, 1871.

Bicknell, Edwin, Boston, Mass. (18). Born in 1830. Died March 19, 1877.

Binney, Amos, Boston, Mass. (1). Born in Boston, Mass., Oct. 18, 1803. Died in Rome, Feb. 18, 1847.

Binney, John, Boston, Mass. (3).

Blackie, Geo. S., Nashville, Tenn. (26).

Blair, Henry W., Washington, D. C. (26). Died Dec. 15, 1884.

Blake, Eli Whitney, New Haven, Conn. (1). Born Jan. 27, 1795. Died Aug. 18, 1886.

Blake, Francis C., Mansfield Valley, Pa. (29). Died Feb. 21, 1891.

Blake, Homer Crane, New York, N. Y. (28). Born in Cleveland, Ohio, Feb. 1, 1822. Died in New York, N. Y., Jan. 20, 1880.
Blanding, William, ——, R. I. (1).
Blatchford, Thomas W., Troy, N. Y. (6).
Blatchley, Miss S. L., New Haven, Conn. (19). Died March 13, 1873.
Boadle, John, Haddonfield, N. J. (20). Born in 1805. Died in July, 1878.
Bomford, George, Washington, D. C. (1). Born in New York, N. Y., 1780. Died in Boston, Mass., March 25, 1848.
Bowditch, Henry Ingersoll, Boston, Mass. (2). Born in Salem, Mass., Aug. 9, 1808. Died in Boston, Mass., Jan. 14, 1892.
Bowles, Miss Margaretta, Columbia, Tenn. (26). Died July, 1887.
Bowron, James, South Pittsburg, Tenn. (26). Died in Dec., 1877.
Bradley, Leverette, Jersey City, N. J. (15). Died in 1875.
Braithwaite, Jos., Chambly, C. W. (11).
Breckinridge, S. M., St. Louis, Mo. (27). Died May 28, 1891.
Briggs, Albert D., Springfield, Mass. (13). Died Feb. 20, 1881.
Briggs, Robert, Philadelphia, Pa. (29). Born May 18, 1822. Died July 24, 1882.
Brigham, Charles Henry, Ann Arbor, Mich. (17). Born in Boston, Mass., July 27, 1820. Died Feb. 19, 1879.
Bross, William, Chicago, Ill. (7). Died in 1890.
Brown, Andrew, Natchez, Miss. (1).
Brown, Horace, Salem, Mass. (27). Died in July, 1883.
Bull, John, Washington, D. C. (31). Born Aug. 1, 1819. Died June 9, 1884.
Bulloch, Walter H., Chicago, Ill. (30).
Burbank, L. S., Woburn, Mass. (18).
Burgess, Edward, Boston, Mass. (22). Born in Barnstable, Mass., June 30, 1848. Died in Boston, July 12, 1891.
Burke, Joseph Chester, Middletown, Conn. (29). Died in 1885.
Burnap, George Washington, Baltimore, Md. (12). Born in Merrimack, N. H., Nov. 30, 1802. Died in Philadelphia, Pa., Sept. 8, 1859.
Burnett, Waldo Irving, Boston, Mass. (1). Born in Southborough, Mass., July 12, 1828. Died in Boston, Mass., July 1, 1854.
Butler, Thomas Belden, Norwalk, Conn. (10). Born Aug. 22, 1806. Died June 8, 1873.

Cairns, Frederick A., New York, N. Y. (27). Died in 1879.
Campbell, Mrs. Mary H., Crawfordsville, Ind. (22). Died Feb. 27, 1882.
Carpenter, Thornton, Camden, S. C. (7).
Carpenter, William M., New Orleans, La. (1).
Case, Leonard, Cleveland, Ohio (15). Born June 27, 1820. Died Jan. 6, 1880.
Case, William, Cleveland, Ohio (6).
Caswell, Alexis, Providence, R. I. (2). Born Jan. 29, 1799. Died in Providence, R. I., Jan. 8, 1877.
Chadbourne, Paul Ansel, Amherst, Mass. (10). Born in North Berwick, Me., Oct. 21, 1823. Died Feb. 23, 1883.
Chapin, J. H., Meriden, Conn. (33). Died in 1892.

Chapman, Nathaniel, Philadelphia, Pa. (1). Born in Alexandria Co., Va., May 28, 1780. Died July 1, 1853.

Chase, Pliny Earle, Haverford College, Pa. (18). Born in Worcester, Mass., Aug. 18, 1820.

Chase, Stephen, Hanover, N. H. (2). Born in 1813. Died Aug. 5, 1851.

Chauvenet, William, St. Louis, Mo. (1). Born May 24, 1819. Died Dec. 13, 1870.

Cheesman, Louis Montgomery, Hartford, Conn. (32). Born in 1858. Died in Jan., 1885.

Cheney, Miss Margaret S., Jamaica Plain, Mass. (29). Died in 1882.

Chevreul, Michel Eugène, Paris, France (35). Born in Angiers, France, Aug. 31, 1786. Died April 9, 1889.

Clapp, Asahel, New Albany, Ind. (1). Born Oct. 5, 1792. Died Dec. 15, 1862.

Clark, Henry James, Cambridge, Mass. (13). Born in Easton, Mass., June 22, 1826. Died in Amherst, Mass., July 1, 1873.

Clark, Joseph, Cincinnati, Ohio (5).

Clark, Patrick, Rahway, N. J. (33). Died March 5, 1887.

Clarke, A. B., Holyoke, Mass. (13).

Cleaveland, C. H., Cincinnati, Ohio (9).

Cleveland, A. B., Cambridge, Mass. (2).

Coffin, James Henry, Easton, Pa. (1). Born in Northampton, Mass., Sept. 6, 1806. Died Feb. 6, 1873.

Coffin, John H. C., Washington, D. C. (1). Born in Wiscasset, Maine, Sept. 14, 1815. Died in Washington, D. C., Jan. 8, 1890.

Coffinberry, Wright Lewis, Grand Rapids, Mich. (20). Born in Lancaster, Ohio, April 5, 1807. Died in Grand Rapids, Mich., March 26, 1889.

Colburn, E. M., Peoria, Ill. (33). Born in Rome, N. Y., Sept. 13, 1813. Died in Peoria, Ill., May 29, 1890.

Cole, Frederick, Montreal, Can. (31). Died in 1887.

Cole, Thomas, Salem, Mass. (1). Born Dec. 24, 1779. Died June 24, 1852.

Coleman, Henry, Boston, Mass. (1).

Collins, Frederick, Washington, D. C. (28). Born Dec. 5, 1842. Died Oct. 27, 1881.

Conrad, Timothy Abbott, Philadelphia, Pa. (1). Born in New Jersey, June 21, 1803. Died Aug. 9, 1877.

Cook, George H., New Brunswick, N. J. (4). Born in Hanover, Morris County, in 1818. Died in New Brunswick, N. J., Sept. 22, 1889.

Cooke, Caleb, Salem, Mass. (18). Born Feb. 15, 1838. Died June 5, 1880.

Cooper, William, Hoboken, N. J. (9). Died in 1864.

Cope, Mary S., Germantown, Pa. (33). Born in Germantown, Pa., July 13, 1853. Died in Germantown, Jan. 4, 1888.

Copes, Joseph S., New Orleans, La. (11). Born Dec. 9, 1811. Died March 1, 1885.

Corning, Erastus, Albany, N. Y. (6). Born in Norwich, Conn., Dec. 14, 1794. Died April 9, 1872.

Costin, M. P., Fordham, N. Y. (30). Died June 8, 1884.

Couper, James Hamilton, Darien, Ga. (1). Born March 5, 1794. Died July 3, 1866.

Cramp, John Mockett, Wolfville, N. S. (11). Born in Kent, England, July 25, 1796. Died Dec. 6, 1881.

Crehore, John D., Cleveland, Ohio (24).

Crocker, Charles F., Lawrence, Mass. (22). Died in July, 1881.

Crocker, Miss Lucretia, Boston, Mass. (29). Died in 1886.

Crosby, Alpheus, Salem, Mass. (10). Born in Sandwich, N. H., Oct. 13, 1810. Died April 17, 1874.

Crosby, Thomas Russell, Hanover, N. H. (18). Born Oct. 22, 1816. Died March 1, 1872.

Crosier, Edward S., New Albany, Ind. (29). Died in June, 1891.

Croswell, Edwin, Albany, N. Y. (6). Born in Catskill, N. Y., May 29, 1797. Died June 18, 1871.

Crow, Wayman, St. Louis, Mo. (27). Born March 7, 1808. Died May 10, 1885.

Cummings, Joseph, Evanston, Ill. (13). Born in Falmouth, Me., March 3, 1817. Died in Evanston, Ill., May 7, 1890.

Curry, W. F., Geneva, N. Y. (11).

Curtis, Josiah, Washington, D. C. (18). Died Aug. 1, 1883.

Cutting, Hiram Adolphus, Lunenburgh, Vt. (17). Born in Concord, Vt., Dec. 23, 1832. Died in Lunenburgh, April 18, 1892.

Da Costa, Chas. M., New York, N. Y. (36). Died in 1890.

Dalrymple, Edwin Augustine, Baltimore, Md. (11). Born in Baltimore, Md., June 4, 1817. Died Oct. 30, 1881.

Danforth, Edward, Elmira, N. Y. (11). Died in Elmira, N. Y., June 13, 1888.

Davenport, H. W., Washington, D. C. (30).

Day, Austin G., New York, N. Y. (29). Died Dec. 28, 1889.

Dayton, Edwin A., Madrid, N. Y. (7). Born in 1827. Died June 24, 1873.

Dean, Amos, Albany, N. Y. (6). Born in Barnard, Vt., Jan. 16, 1803. Died Jan. 26, 1868.

Dearborn, George H. A. S., Roxbury, Mass. (1).

Dekay, James Ellsworth, New York, N. Y. (1). Born in New York, 1792. Died Nov. 21, 1851.

Delano, Joseph C., New Bedford, Mass. (5). Born Jan. 9, 1796. Died Oct. 16, 1886.

De Laski, John, Carver's Harbor, Me. (18).

Devereux, John Henry, Cleveland, Ohio (18). Born in Boston, Mass., April 5, 1832. Died in Cleveland, Ohio, March 17, 1886.

Dewey, Chester, Rochester, N. Y. (1). Born in Sheffield, Mass., Oct. 25, 1781. Died Dec. 15, 1867.

Dexter, G. M., Boston, Mass. (11).

Dickerson, Edward N., New York, N. Y. (36).

Dillingham, W. A. P., Augusta, Me. (17).

Dimmick, L. N., Santa Barbara, Cal. (29). Died May 31, 1884.

Dinwiddie, Hardaway H., College Station, Texas (32). Died Dec. 11, 1887.

Dinwiddie, Robert, New York, N. Y. (1). Born in Dumfries, Scotland, July 23, 1811. Died in New York, N. Y., July 12, 1888.

Dixwell, Geo. B., Boston, Mass. (29). Died April, 1885.

Doggett, George Newell, Chicago, Ill. (33). Born in Chicago, Ill., Dec. 19, 1858. Died in Fredericksburg, Va., Jan. 15, 1887.

Doggett, Mrs. Kate Newell, Chicago, Ill. (17). Born in Castleton, Vt., Nov. 5, 1828. Died in Havana, Cuba, March 13, 1884.

Doggett, Wm. E., Chicago, Ill. (17). Born Nov. 20, 1820. Died in 1876.

Doolittle, L., Lenoxville, C. E. (11). Died in 1862.

Dorr, Ebenezer Pearson, Buffalo, N. Y. (25). Born in Hartford, Vt. Died in Buffalo, N. Y., April 29, 1882.

Draper, Henry, New York, N. Y. (28). Born in New York, N. Y., March 7, 1837. Died Nov. 20, 1882.

Ducatel, Julius Timoleon, Baltimore, Md. (1). Born in Baltimore, Md., June 6, 1798. Died April 25, 1849.

Duffield, George, Detroit, Mich. (10). Born in Strasburg, Pa., July 4, 1794. Died in Detroit, Mich., June 26, 1869.

Dumont, A. H., Newport, R. I. (14).

Dun, Walter Angus, Cincinnati, Ohio (31). Born March 1, 1857. Died Nov. 7, 1887.

Duncan, Lucius C., New Orleans, La. (10). Born in 1801. Died Aug. 9, 1855.

Dunn, R. P., Providence, R. I. (14).

Dury, Henry M., Nashville, Tenn. (33). Died April 15, 1891.

Eads, James Buchanan, New York, N. Y. (27). Born May 23, 1820. Died March 8, 1887.

Easton, Norman, Fall River, Mass. (14). Died Dec. 21, 1872.

Eaton, James H., Beloit, Wis. (17). Died Jan. 5, 1877.

Elliott, Ezekiel Brown, Washington, D. C. (10). Born July 16, 1823. Died May 24, 1888.

Elsberg, Louis, New York, N. Y. (23). Born in Iserlohn, Prussia, April 2, 1836. Died in New York, N. Y., Feb. 19, 1885.

Elwyn, Alfred Langdon, Philadelphia, Pa. (1). Born in Portsmouth, N. H., July 9, 1804. Died in Philadelphia, Pa., March 15, 1884.

Ely, Charles Arthur, Elyria, Ohio (4).

Emerson, Geo. Barrell, Boston, Mass. (1). Born in Kennebunk, Me., Sept. 12, 1797. Died March 14, 1881.

Emmons, Ebenezer, Williamstown, Mass. (1). Born in Middlefield, Mass., May 16, 1799. Died October 1, 1863.

Engelmann, George, St. Louis, Mo. (1). Born in Frankfort-on-the Main, Germany, Feb. 2, 1809. Died Feb. 4, 1884.

Engstrom, A. B., Burlington, N. J. (1).

Eustis, Henry Lawrence, Cambridge, Mass. (2). Born Feb. 1, 1819. Died Jan. 11, 1885.

Evans, Asher B., Lockport, N. Y. (19). Born in Hector, N. Y., Sept. 21, 1834. Died in Lockport, Sept. 24, 1891.

Evans, Edwin, Streator, Ill. (30). Died May 5, 1889.

Everett, Edward, Boston, Mass. (2). Born in Dorchester, Mass., April 11, 1794. Died in Boston, Mass., Jan. 15, 1865.

Ewing, Thomas, Lancaster, Ohio (5). Born in Ohio Co., Va., Dec. 28, 1789. Died Oct. 26, 1871.

Faries, R. J., Wauwatosa, Wis. (21). Died May 31, 1878.

Farnam, J. E., Georgetown, Ky. (26).

Farquharson, Robert James, Des Moines, Iowa (24). Born July 15, 1824. Died Sept. 6, 1884.

Felton, Samuel Morse, Philadelphia, Pa. (29). Born in Newbury, Mass., July 19, 1809. Died in Philadelphia, Pa., Jan. 24, 1889.

Ferrel, William, Kansas City, Mo. (11). Died Sept. 18, 1891.

Ferris, Isaac, New York, N. Y. (6). Born in New York, Oct. 9, 1798. Died in Roselle, N. J., June 16, 1873.

Feuchtwanger, Lewis, New York, N. Y. (11). Born in Fürth, Bavaria, Jan. 11, 1805. Died in New York, N. Y., June 25, 1876.

Ficklin, Joseph, Columbia, Mo. (20). Born in Winchester, Ky., Sept. 9, 1833. Died in Columbia, Mo., Sept. 6, 1887.

Fillmore, Millard, Buffalo, N. Y. (7). Born in New York, Jan. 7, 1800. Died March 8, 1874.

Fisher, Mark, Trenton, N. J. (10).

Fitch, Alexander, Hartford, Conn. (1). Born March 25, 1799. Died Jan. 20, 1859.

Fitch, O. H., Ashtabula, Ohio (7). Born in 1803. Died Sept. 17, 1882.

Floyd, Richard S., San Francisco, Cal. (34). Died Oct. 17, 1890.

Foote, Herbert Carrington, Cleveland, Ohio (35). Born in 1852. Died in Cleveland, Aug. 24, 1888.

Forbush, E. B., Buffalo, N. Y. (15).

Force, Peter, Washington, D. C. (4). Born in New Jersey, Nov. 26, 1790. Died in Washington, D. C., Jan. 23, 1868.

Ford, A. C., Nashville, Tenn. (26).

Forshey, Caleb Goldsmith, New Orleans, La. (21). Born in Somerset Co., Pa., July 18, 1812. Died in Carrollton, La., July 25, 1881.

Foster, John Wells, Chicago, Ill. (1). Born in Brimfield, Mass., March 4, 1815. Died in Chicago, Ill., June 29, 1873.

Foucon, Felix, Madison, Wis. (18).

Fowle, Wm. Bentley, Boston, Mass. (1). Born in Boston, Mass., Oct. 17, 1795. Died Feb. 6, 1865.

Fox, Charles, Grosse Ile, Mich. (7).

Fox, Joseph G., Easton, Pa. (31). Born in Adams, N. Y., Sept. 7, 1833. Died in Easton, Pa., Dec. 27, 1889.

Frazer, John Fries, Phila., Pa. (1). Born July 8, 1812. Died Oct. 12, 1872.

Freeman, Spencer Hedden, Cleveland, Ohio (29). Born Oct. 3, 1855. Died Feb. 2, 1886.

French, John William, West Point, N. Y. (11). Born in Connecticut, about 1810. Died in West Point, N. Y., July 8, 1871.
Frothingham, Frederick, Milton, Mass. (11). Born in Montreal, P. Q., April 9, 1825. Died in Milton, March 19, 1891.
Fuller, H. Weld, Boston, Mass. (29). Died Aug. 14, 1889.

Garber, A. P., Columbia, Pa. (29). Died Aug. 26, 1881.
Gardiner, Frederic, Middletown, Conn. (23). Born in Gardiner, Me., Oct. 22, 1822. Died in Middletown, Conn., July 17, 1889.
Garrison, H. D., Chicago, Ill. (31). Died in Feb., 1891.
Gavit, John E., New York, N. Y. (1). Born in New York, Oct. 29, 1819. Died in Stockbridge, Mass., Aug. 25, 1874.
Gay, Martin, Boston, Mass. (1). Born in 1804. Died Jan. 12, 1850.
Gibbon, J. H., Charlotte, N. C. (3).
Gillespie, William Mitchell, Schenectady, N. Y. (10). Born in New York, N. Y., 1816. Died in New York, Jan. 1, 1868.
Gilmor, Robert, Baltimore, Md. (1).
Glazier, W. W., Key West, Fla. (29). Died Dec. 11, 1880.
Goldmark, J., New York, N. Y. (29). Died in April, 1882.
Gould, Augustus Addison, Boston, Mass. (11). Born April 23, 1805. Died Sept. 15, 1866.
Gould, Benjamin Apthorp, Boston, Mass. (2). Born in Lancaster, Mass., June 15, 1787. Died Oct. 24, 1859.
Graham, James D., Washington, D. C. (1). Born in Virginia, 1799. Died in Boston, Mass., Dec. 28, 1865.
Gray, Alonzo, Brooklyn, N. Y. (13). Born in Townshend, Vt., Feb. 21, 1808. Died in Brooklyn, N. Y., March 10, 1860.
Gray, Asa, Cambridge, Mass. (1). Born in Paris, N. Y., Nov. 18, 1810. Died in Cambridge, Mass., Jan. 30, 1888.
Gray, James H., Springfield, Mass. (6).
Greene, Benjamin D., Boston, Mass. (1). Died Oct. 14, 1862, aged 68.
Greene, Everett W., Madison, N. J. (10). Died in 1864.
Greene, Samuel, Woonsocket, R. I. (9). Died in 1868.
Greer, James, Dayton, Ohio (20). Died in Feb., 1874.
Griffith, Robert Eglesfield, Philadelphia, Pa. (1). Born in Philadelphia, Pa., Feb. 13, 1798. Died June 26, 1854.
Griswold, John Augustus, Troy, N. Y. (19). Born Nov. 11, 1818. Died Oct. 31, 1872.
Guest, William E., Ogdensburg, N. Y. (6).
Guyot, Arnold, Princeton, N. J. (1). Born Sept. 5, 1809. Died Feb. 8, 1884.

Habel, Louis, Northfield, Vt. (34).
Hackley, Charles William, New York, N. Y. (4). Born in Herkimer Co., N. Y., March 9, 1809. Died in New York, N. Y., January 10, 1861.
Hadley, George, Buffalo, N. Y. (6). Born June, 1813. Died Oct. 16, 1877.
Haldeman, Samuel Stehman, Chickies, Pa. (1). Born Aug. 12, 1812. Died Sept. 10, 1880.

Hale, Enoch, Boston, Mass. (1). Born in Westhampton, Mass., Jan. 29, 1790. Died in Boston, Mass., Nov. 12, 1848.

Hamilton, Jno. M., Coudersport, Pa. (33).

Hampson, Thomas, Washington, D. C. (33).

Hance, Ebenezer, Fallsington P. O., Pa. (7). Died in 1876.

Harding, Myron H., Lawrenceburg, Ind. (30.) Died Sept., 1885.

Hare, Robert, Philadelphia, Pa. (1). Born in Philadelphia, Pa., Jan. 17, 1781. Died in Philadelphia, May 15, 1858.

Harger, Oscar, New Haven, Conn. (25). Born in Oxford, Conn., Jan. 12, 1843. Died in New Haven, Conn., Nov. 6, 1887.

Harlan, Joseph G., Haverford, Pa. (8).

Harlan, Richard, Philadelphia, Pa. (1). Born in Philadelphia, Pa., Sept. 19, 1796. Died in New Orleans, La., Sept. 30, 1843.

Harris, Thaddeus William, Cambridge, Mass. (1). Born in Dorchester, Mass., Nov. 12, 1795. Died in Cambridge, Mass., Jan. 16, 1856.

Harrison, A. M., Plymouth, Mass. (29).

Harrison, Benjamin Franklin, Wallingford, Conn. (11). Born April 19, 1811. Died April 23, 1886.

Harrison, Jos., jr., Philadelphia, Pa. (12). Born in Philadelphia, Pa., Sept. 20, 1810. Died in Philadelphia, March 27, 1874.

Hart, Simeon, Farmington, Conn. (1). Born Nov. 17, 1795. Died April 20, 1853.

Hartt, Charles Frederick, Ithaca, N. Y. (18). Born in Nova Scotia, Aug. 20, 1840. Died March 18, 1878.

Haven, Joseph, Chicago, Ill. (17). Born in Dennis, Mass., Jan. 4, 1816. Died May 23, 1874.

Hawes, George W., Washington, D. C. (23). Born Dec. 31, 1848. Died June 22, 1882.

Hayden, Ferdinand Vandeveer, Philadelphia, Pa. (29). Born in Westfield, Mass., Sept. 7, 1829. Died Dec. 22, 1887.

Hayden, Horace H., Baltimore, Md. (1). Born in Windsor, Conn., Oct. 13, 1769. Died in Baltimore, Md., Jan. 26, 1844.

Hayes, George E., Buffalo, N. Y. (15).

Hayward, James, Boston, Mass. (1). Born in Concord, Mass., June 12, 1786. Died in Boston, Mass., July 27, 1866.

Hazen, William Babcock, Washington, D. C. (30). Born in Hartford, Vt., Sept. 27, 1830. Died Jan. 16, 1887.

Hedrick, Benjamin Sherwood, Washington, D. C. (19). Born in 1826. Died Sept. 2, 1886.

Heighway, A. E., Cincinnati, Ohio (29). Born Dec. 26, 1820. Died Jan. 24, 1888.

Hempstead, G. S. B., Portsmouth, Ohio (29). Born in 1795. Died July 9, 1883.

Henry, Joseph, Washington, D. C. (1). Born in Albany, N. Y., Dec. 17, 1797. Died May 13, 1878.

Hickox, S. V. R., Chicago, Ill. (17). Died in 1872.

Hicks, William C., New York, N. Y. (34). Died in 1885.

Hilgard, Julius Erasmus, Washington, D. C. (4). Born in Zweibrücken, Bavaria, Jan. 7, 1825. Died in Washington, D. C., May 8, 1891.

Hilgard, Theodore Charles, St. Louis, Mo. (17). Born in Zweibrücken, Bavaria, Feb. 28, 1828. Died March 5, 1875.

Hill, Walter N., Chester, Pa. (29). Born Apr. 15, 1846. Died Mar. 25, 1884.

Hincks, William, Toronto, C. W. (11). Born in 1801. Died July, 1871.

Hitchcock, Edward, Amherst, Mass. (1). Born in Deerfield, Mass., May 24, 1793. Died Feb. 27, 1864.

Hoadley, John Chipman, Boston, Mass. (29). Born Dec. 10, 1818 Died Oct. 21, 1886.

Hobbs, A. C., Bridgeport, Conn. (28). Died in Nov., 1891.

Hodgson, W. B., Savannah, Ga. (10). Born 1815.

Holbrook, John Edwards, Charleston, S. C. (1). Born in Beaufort, S. C. Dec. 30, 1796. Died in Norfolk, Mass., Sept. 8, 1871.

Holman, Mrs. S. W., Boston, Mass. (29). Died May 5, 1885.

Holmes, Edward J., Boston, Mass. (29). Died in July, 1884.

Homes, Henry A., Albany, N. Y. (11). Born in Boston, Mass., March 10, 1812. Died in Albany, N. Y., Nov. 3, 1887.

Hopkins, Albert, Williamstown, Mass. (19). Born July 14, 1807. Died May 25, 1872.

Hopkins, James G., Ogdensburg, N. Y. (10). Died in 1860.

Hopkins, T. O., Williamsville, N. Y. (10). Died in 1866.

Hopkins, Wm., Lima, N. Y. (5). Died in March, 1867.

Hoppock, Albert Eugene, Hastings-on-Hudson, N.Y. (29).

Horton, C. V. R., Chaumont, N. Y. (10). Died in 1862.

Horton, William, Craigville, N. Y. (1).

Hosford, Benj. F., Haverhill, Mass. (13). Died in 1864.

Hough, Franklin Benjamin, Lowville, N. Y. (4). Born in Martinsburgh, N. Y., July 20, 1822. Died June 11, 1885.

Houghton, Douglas, Detroit, Mich. (1). Born in Troy, N. Y., Sept. 21, 1809. Died Oct. 13, 1845.

Hovey, Edmund O., Crawfordsville, Ind. (20). Born July 15, 1801. Died March 10, 1877.

Howland, Edward Perry, Washington, D. C. (29). Born in Ledyard, N. Y., July 20, 1825. Died in Harrisburg, Pa., Sept. 12, 1888.

Hubbert, James, Richmond, Province of Quebec (16). Died in 1868.

Howland, Theodore, Buffalo, N. Y. (15).

Hunt, Edward Bissell, Washington, D. C. (2). Born in Livingston Co., N. Y., June 15, 1822. Died in Brooklyn, N. Y., Oct. 2, 1863.

Hunt, Freeman, New York, N. Y. (11). Born in Quincy, Mass., March 21, 1804. Died in Brooklyn, N. Y., March 2, 1858.

Hunt, Thomas Sterry, New York, N. Y. (1). Born in Norwich, Conn., Sept. 5, 1826. Died in New York, N. Y., Feb. 12, 1892.

Hyatt, Theodore, Chester, Pa. (30).

Ives, Moses B., Providence, R. I. (9). Died in 1857.

Ives, Thomas P., Providence, R. I. (10).

Jackson, Charles Thomas, Boston, Mass. (1). Born in Plymouth, Mass., June 21, 1805. Died Aug. 28, 1880.

James, Thomas Potts, Cambridge, Mass. (22). Born Sept. 1, 1803. Died Feb. 22, 1882.

Jeffries, John Amory, Boston, Mass. (38). Born in Milton, Mass., Sept. 2, 1859. Died in Boston, Mass., March 26, 1892.

Johnson, Hosmer A., Chicago, Ill. (17). Died in Chicago, Feb. 26, 1891.

Johnson, Walter Rogers, Washington, D. C. (1). Born in Leominster, Mass., June 21, 1794. Died April 26, 1852.

Johnson, William Schuyler, Washington, D. C. (31). Born Sept. 20, 1859. Died Oct. 6, 1883.

Jones, Catesby A. R., Washington, D. C. (8).

Jones, Henry A., Portland, Me. (29). Died Sept. 3, 1883.

Jones, James H., Boston, Mass. (28).

Joy, Charles Arad, Stockbridge, Mass. (8). Born in Ludlowville, N. Y., Oct. 8, 1823. Died in Stockbridge, Mass., May 29, 1891.

Kedzie, W. K., Oberlin, Ohio (25). Born in Kalamazoo, Mich., July 5, 1851. Died in Lansing, Mich., Apr. 10, 1880.

Keely, George W., Waterville, Me. (1). Died in 1878.

Keep, N. C., Boston, Mass. (13). Died in March, 1875.

Kennicott, Robert, West Northfield, Ill. (12). Born Nov. 13, 1835. Died in 1866.

Kerr, Washington Caruthers, Raleigh, N. C. (10). Born May 24, 1827. Died Aug. 9, 1885.

Kidder, Henry Purkitt, Boston, Mass. (29). Born Jan. 8, 1823. Died Jan. 28, 1886.

King, Mitchell, Charleston, S. C. (3). Born in Scotland, June 8, 1783. Died Nov. 12, 1862.

Kirkpatrick, James A., Philadelphia, Pa. (7). Died June 3, 1886.

Kite, Thomas, Cincinnati, Ohio (5). Died Feb. 6, 1884.

Klippart, John H., Columbus, Ohio (17). Died October, 1878.

Knickerbocker, Charles, Chicago, Ill. (17). Died in 1873.

Knight, J. B., Philadelphia, Pa. (21). Died March 10, 1879.

Lacey, O. M., Crawfordsville, Ind. (39). Died Jan. 9, 1891.

Lacklan, R., Cincinnati, Ohio (11).

Lapham, Increase Allen, Milwaukee, Wis. (3). Born in Palmyra, N. Y., March 7, 1811. Died in Oconomowoc, Wis., Sept. 14, 1875.

Larkin, Ethan Pendleton, Alfred Centre, N. Y. (33). Born Sept. 20, 1829. Died Aug. 23, 1887.

LaRoche, Réné, Philadelphia, Pa. (12). Born in Philadelphia, Pa., 1795. Died in Philadelphia, Dec., 1872.

Lasel, Edward, Williamstown, Mass. (1). Born Jan. 21, 1809. Died Jan. 31, 1852.

Lawford, Frederick, Montreal, Canada (11). Died in 1866.

Lawrence, Edward, Charlestown, Mass. (18). Born June, 1810. Died Oct. 17, 1885.

Lea, Isaac, Philadelphia, Pa. (1). Born in Wilmington, Del., March 4, 1792. Died Dec. 8, 1886.

Le Conte, John Lawrence, Philadelphia, Pa. (1). Born in New York, May 13, 1825. Died Nov. 15, 1883.

Lederer, Baron von, Washington, D. C. (1).

Leidy, Joseph, Philadelphia, Pa. (7). Born in Philadelphia, Sept. 9, 1823. Died in Philadelphia, April 30, 1891.

Leonard, Rensselaer, Mauch Chunk, Pa. (33). Born in Hancock, N. Y., April 12, 1821. Died in Mauch Chunk, Pa., Oct. 26, 1888.

Lewis, Henry Carvill, Philadelphia, Pa. (26). Born in Philadelphia, Pa., Nov. 16, 1853. Died in Manchester, England, July 21, 1888.

Libbey, Joseph. Georgetown, D. C. (31). Died July 20, 1886.

Lieber, Oscar Montgomery, Columbia, S. C. (8). Born Sept. 8, 1830. Died June 27, 1862.

Lincklaen, Ledyard, Cazenovia, N. Y. (1). Born in Cazenovia, N. Y., Oct. 17, 1820. Died April 25, 1864.

Linsley, James Harvey, Stafford, Conn. (1). Born in Northford, Conn., May 5, 1787. Died in Stratford, Conn., Dec. 26, 1843.

Lockwood, Moses B., Providence, R. I. (9). Died in 1872.

Logan, William Edmond, Montreal, Canada (1). Born in Montreal, Canada, April 23, 1798. Died in Wales, June 22, 1875.

Loiseau, Emile F., Brussels, Belgium (33). Died April 30, 1886.

Loomis, Elias, New Haven, Conn. (1). Born in Willington, Conn., Aug. 7, 1811. Died in New Haven, Conn., Aug. 15, 1889.

Loosey, Charles F., New York, N. Y. (12).

Lothrop, Joshua R., Buffalo, N. Y. (15).

Lovering, Joseph, Cambridge, Mass. (2). Born in Charlestown, Mass., Dec. 25, 1813. Died in Cambridge, Mass., Jan. 18, 1892.

Lowrie, J. R., Warriorsmark, Pa. (29). Died Dec. 10, 1885.

Lull, Edward Phelps, Washington, D. C. (28). Born Feb. 20, 1836. Died March 5, 1887.

Lyford, Moses, Springfield, Mass. (22). Born in Mt. Vernon, Me., Jan. 31, 1816. Died in Portland, Me., Aug. 4, 1887.

Lyman, Chester Smith, New Haven, Conn. (4). Born in Manchester, Conn., Jan. 13, 1814. Died in New Haven, Conn., in 1889.

Lyon, Sidney S., Jeffersonville, Ind. (20). Born Aug. 4, 1808. Died June 24, 1872.

M'Conihe, Isaac, Troy, N. Y. (5).

McCutchen, A. R., Atlanta, Ga. (25). Died Nov. 21, 1887.

McElrath, Thomas, New York, N. Y. (36). Born in Williamsport, Pa., May 1, 1807. Died in New York, N. Y., June 6, 1888.

McFadden, Thomas, Westerville, Ohio (30). Born Nov. 9, 1825. Died Nov. 9, 1883.

McFarland, Walter, New York, N. Y. (36). Died July 22, 1888.

MacGregor, Donald, Houston, Texas (33). Died in Oct., 1887.

McLachlan, J. S., Montreal, Can. (31).
McMahon, Mathew, Albany, N. Y. (11).
McNiel, John A., Binghamton, N. Y. (35). Died in Binghamton, Dec. 20, 1891, aged 75.
Maack, G. A., Cambridge, Mass. (18). Died in Aug., 1873.
Macfarlane, James, Towanda, Pa. (29). Died in 1885.
Mackintosh, James B , New York, N. Y. (27). Died in 1891.
Maffet, Wm. Ross, Wilkes Barre, Pa. (33). Died in June, 1890.
Mahan, Dennis Hart, West Point, N. Y. (9). Born in New York, N. Y., April 2, 1802. Died in New York, Sept. 16, 1871.
Marler, George L., Montreal, Can. (31).
Marsh, Dexter, Greenfield, Mass. (1). Born in Montague, Mass., Aug. 22, 1806. Died in Greenfield, Mass., April 2, 1853.
Marsh, James E., Roxbury, Mass. (10).
Martin, Benjamin Nichols, New York, N. Y. (23). Born in Mount Holly, N. J., Oct. 20, 1816. Died in New York, N. Y., Dec. 26, 1883.
Mather, William Williams, Columbus, Ohio (1). Born in Brooklyn, Conn., May 24, 1804. Died in Columbus, Ohio, Feb. 27, 1859.
Maude, John B., St. Louis, Mo. (27). Died in April, 1879.
Maupin, S., Charlottesville, Va. (10).
May, Abigail Williams, Boston, Mass. (29). Born in Boston, April 21, 1829. Died in Boston, Nov. 30, 1888.
Meade, George Gordon, Philadelphia, Pa. (15). Born Dec. 30, 1815. Died Nov. 6, 1872.
Meek, Fielding Bradford, Washington, D. C. (6). Born Dec. 10, 1817. Died Dec. 21, 1876.
Meigs, James Aitken, Philadelphia, Pa. (12). Born July 30, 1829. Died Nov. 9, 1879.
Metcalf, Caleb B., Worcester, Mass. (20). Died July 31, 1891.
Minifie, Wm., Baltimore, Md. (12). Born Aug. 14, 1805. Died Oct. 24, 1880.
Mitchel, Ormsby MacKnight, Cincinnati, Ohio (3). Born in Union Co., Ky., July 28, 1810. Died in Beaufort, S. C., Oct. 30, 1862.
Mitchell, Miss Maria, Lynn, Mass. (4). Born in Nantucket, Mass., Aug. 1, 1818. Died in Lynn, 1889.
Mitchell, William, Poughkeepsie, N. Y. (2). Born in Nantucket, Mass., Dec. 20, 1791. Died in Poughkeepsie, N. Y., April 19, 1868.
Mitchell, Wm. H., Florence, Ala. (17).
Monroe, Nathan, Bradford, Mass. (6). Born in Minot, Me., May 16, 1804. Died in Bradford, Mass., July 8, 1866.
Monroe, William, Concord, Mass. (18). Died April 27, 1877.
Moore, E. C., New York, N. Y. (30).
Morgan, Lewis Henry, Rochester, N. Y. (10). Born near Aurora, N. Y., Nov. 21, 1818. Died Dec. 17, 1881.
Morgan, Mrs. Mary E., Rochester, N. Y. (31). Died in 1884.
Morison, N. H., Baltimore, Md. (17). Born in 1815. Died Nov. 14, 1890.
Morris, John B., Nashville, Tenn. (26).
Morris, Wistar, Philadelphia, Pa. (33). Died March 23, 1891.

Morton, Samuel George, Philadelphia, Pa. (1). Born in Philadelphia, Pa., Jan. 26, 1799. Died in Philadelphia, May 15, 1851.

Mott, Alexander B., New York, N. Y. (36). Died Aug. 12, 1889.

Mudge, Benjamin Franklin, Manhattan, Kansas (25). Born in Orrington, Me., Aug. 11, 1817. Died Nov. 21, 1879.

Muir, William, Montreal, Can. (31). Died July, 1885.

Mussey, William Heberdom, Cincinnati, Ohio (30). Born Sept. 30, 1818. Died Aug. 1, 1882.

Nagel, Herman, St. Louis, Mo. (30). Born in Tritzwalk, Germany, May 28, 1820. Died in St. Louis, Mo., Feb. 16, 1889.

Newland, John, Saratoga Springs, N. Y. (28). Died Jan. 18, 1880.

Newton, E. H., Cambridge, N. Y. (1).

Nichols, Charles A., Providence, R. I. (17). Born Jan. 4, 1826. Died Oct. 20, 1877.

Nichols, William Ripley, Boston, Mass. (18). Born April 30, 1847. Died July 14, 1886.

Nicholson, Thomas, New Orleans, La. (21).

Nicollet, Jean Nicholas, Washington, D. C. (1). Born in Savoy, France, July 24, 1786. Died in Washington, D. C., Sept. 11, 1843.

Northrop, John I., New York, N. Y. (36).

Norton, John Pitkin, New Haven, Conn. (1). Born July 19, 1822. Died Sept. 5, 1852.

Norton, William Augustus, New Haven, Conn. (6). Born in East Bloomfield, N. Y., Oct. 25, 1810. Died Sept. 21, 1883.

Noyes, James Oscar, New Orleans, La. (21). Born in Niles, N. Y., June 14, 1829. Died in New Orleans, La., Sept. 11, 1872.

Nutt, Cyrus, Bloomington, Ind. (20). Born in Trumbull Co., Ohio, Sept. 4, 1814. Died in Bloomington, Aug. 23, 1875.

Oakes, Wm., Ipswich, Mass. (1). Born July 1, 1799. Died July 31, 1848.

Ogden, Robert W., New Orleans, La. (21). Died March 24, 1878.

Ogden, William Butler, High Bridge, N. Y. (17). Born in New York, N. Y., 1805. Died in New York, Aug. 3, 1877.

Oliver, Miss Mary E., Ithaca, N. Y. (20).

Olmsted, Alexander Fisher, New Haven, Conn. (4). Born Dec. 20, 1822. Died May 5, 1853.

Olmsted, Denison, New Haven, Conn. (1). Born in East Hartford, Conn., June 18, 1791. Died in New Haven, Conn., May 18, 1859.

Olmsted, Denison, jr., New Haven, Conn. (1). Born Feb. 16, 1824. Died Aug. 15, 1846.

Orton, James, Poughkeepsie, N. Y. (18). Born in Seneca Falls, N. Y., April 21, 1830. Died in Peru, S. A., Sept. 24, 1877.

Osbun, Isaac J., Salem, Mass. (29).

Otis, George Alexander, Washington, D. C. (10). Born in Boston, Mass., Nov. 12, 1830. Died Feb. 23, 1881.

Owen, Richard, New Harmony, Ind. (20). Born in Scotland, Jan. 6, 1810. Died in New Harmony, March 24, 1890.

Packer, Harry E., Mauch Chunk, Pa. (30). Died Feb. 1, 1884.
Painter, Jacob, Lima, Pa. (23). Died in 1876.
Painter, Minshall, Lima, Pa. (7).
Parker, Wilbur F., West Meriden, Conn. (23). Died in 1876.
Parkman, Samuel, Boston, Mass. (1). Born in 1816. Died Dec. 15, 1854.
Parry, Charles C., Davenport, Iowa (6). Born in Admington, Worcestershire, Eng., Aug. 28, 1823. Died in Davenport, Iowa, Feb. 20, 1890.
Parsons, Henry Betts, New York, N. Y. (30). Born Nov. 20, 1855. Died Aug. 21, 1885.
Payn, Charles H., Saratoga Springs, N. Y. (28). Born May 16, 1814. Died Dec. 20, 1881.
Pearson, H. G., New York, N. Y. (36).
Pease, F. S., Buffalo, N. Y. (35). Died Nov. 6, 1890.
Pease, Rufus D., Philadelphia, Pa. (33). Died in 1890.
Peirce, Benjamin Osgood, Beverly, Mass. (18). Born in Beverly, Sept. 26, 1812. Died in Beverly, Nov. 12, 1883.
Peirce, Benjamin, Cambridge, Mass. (1). Born in Salem, Mass., April 4, 1809. Died in Cambridge, Mass., Oct. 6, 1880.
Perch, Bernard, Frankford, Pa. (35). Born in 1850. Died in 1887.
Perkins, George Roberts, Utica, N. Y. (1). Born in Otsego Co., N. Y., May 3, 1812. Died in New Hartford, N. Y., Aug. 22, 1876.
Perkins, Henry C., Newburyport, Mass. (18). Born Nov. 13, 1804. Died Feb. 2, 1873.
Perry, John B., Cambridge, Mass. (16). Born in 1820. Died Oct. 3, 1872.
Perry, Matthew Calbraith, New York, N. Y. (10). Born in South Kingston, R. I., 1795. Died in New York, March 4, 1858.
Phelps, Mrs. Almira Hart Lincoln, Baltimore, Md. (13). Born in Berlin, Conn., July 15, 1793. Died in Berlin, July 15, 1884.
Philbrick, Edw. S., Brookline, Mass. (29). Born in Boston, Mass., Nov. 20, 1827. Died in Brookline, Mass., Feb. 13, 1889.
Phillips, John C., Boston, Mass. (29). Born in 1839. Died Mar. 1, 1885.
Piggot, A. Snowden, Baltimore, Md. (10).
Pim, Bedford Clapperton Trevelyan, London, Eng. (33). Born in England, June 12, 1826. Died Oct., 1886.
Platt, W. G., Philadelphia, Pa. (32). Died Nov., 1885.
Plumb, Ovid, Salisbury, Conn. (9).
Pope, Charles Alexander, St. Louis, Mo. (12). Born in Huntsville, Ala., March 15, 1818. Died in Paris, Mo., July 6, 1870.
Porter, John Addison, New Haven, Conn. (14). Born in Catskill, N. Y., March 15, 1822. Died in New Haven, Conn., Aug. 25, 1866.
Potter, Stephen H., Hamilton, Ohio (30). Born Nov. 10, 1812. Died Dec. 9, 1883.
Pourtalès, Louis François de, Cambridge, Mass. (1). Born March 4, 1824. Died July 19, 1880.
Pruyn, John Van Schaick Lansing, Albany, N. Y. (1). Born in Albany, N. Y., June 22, 1811. Died in Clifton Springs, N. Y., Nov. 21, 1877.
Pugh, Evan, Centre Co., Pa. (14). Born Feb. 29, 1828. Died April 29, 1864.

Pulsifer, Sidney, Philadelphia, Pa. (21). Died March 24, 1884.

Putnam, Mrs. Frederick Ward, Cambridge, Mass. (19). Born in Charlestown, Mass., Dec. 29, 1838. Died in Cambridge, Mass., March 10, 1879.

Putnam, J. Duncan, Davenport, Iowa (27). Born Oct. 18, 1855. Died Dec. 10, 1881.

Read, Ezra, Terre Haute, Ind. (20). Died in 1877.

Redfield, William C., New York, N. Y. (1). Born near Middletown, Conn., March 26, 1789. Died Feb. 12, 1857.

Resor, Jacob, Cincinnati, Ohio (8). Died in 1871.

Richardson, Tobias G., New Orleans, La. (30). Died in New Orleans, May 26, 1892. Aged 65 years.

Robb, James, Fredericton, N. B. (4).

Robinson, Coleman T., Buffalo, N. Y. (15). Born in Putnam Co., N. Y., in 1838. Died near Brewster's Station, N. Y., May 1, 1872.

Rochester, Thomas Fortescue, Buffalo, N. Y. (35). Born Oct. 8, 1823. Died May 24, 1887.

Rockwell, John Arnold, Norwich, Conn. (10). Born in Norwich, Conn., August 27, 1803. Died in Washington, D. C., February 10, 1861.

Roeder, F. A., Cincinnati, Ohio (30).

Rogers, Henry Darwin, Glasgow, Scotland (1). Born in Philadelphia, Pa. Aug. 1, 1808. Died in Glasgow, Scotland, May 29, 1866.

Rogers, James Blythe, Philadelphia, Pa. (1). Born in Philadelphia, Pa., Feb. 11, 1802. Died in Philadelphia, June 15, 1852.

Rogers, Robert Emple, Philadelphia, Pa. (18). Born in Baltimore, Md., March 29, 1813. Died Sept. 6, 1884.

Rogers, William Barton, Boston, Mass. (1). Born in Philadelphia, Pa., Dec. 7, 1804. Died in Boston, May 30, 1882.

Root, Elihu, Amherst, Mass. (25). Born Sept. 14, 1845.

Rutherford, Lewis M., New York, N. Y. (13). Born in Morrisania, N. Y., Nov. 25, 1816. Died in Tranquility, N. J., May 30, 1892.

Sager, Abram, Ann Arbor, Mich. (6). Born in Bethlehem, N. Y., Dec. 22, 1811. Died in Ann Arbor, Mich., August 6, 1877.

Sanders, Benjamin D., Wellsburg, W. Va. (19).

Scammon, Jonathan Young, Chicago, Ill. (17). Born in Whitefield, Me., in 1812. Died in Chicago, Ill., March 17, 1890.

Schaeffer, Geo. C., Washington, D. C. (1). Died in 1873.

Schimpff, Robert D., Scranton, Pa. (36).

Schley, William, New York, N. Y. (28). Died in 1882.

Schram, Nicholas Hallock, Newburgh, N. Y. (33). Died in Newburgh, N. Y., aged 54 years, 1 month and 2 days.

Schrenk, Joseph, Hoboken, N. J. (36).

Scott, Joseph, Dunham, C. E. (11). Died in 1865.

Seaman, Ezra Champion, Ann Arbor, Mich. (20). Born Oct. 14, 1805. Died July 15, 1880.

Senecal, L. A., Montreal, Can. (31).

Senter, Harvey S., Aledo, Ill. (20). Died in 1875.

Seward, William Henry, Auburn, N. Y. (1). Born in Florida, N. Y., May 16, 1801. Died in Auburn, N. Y., Oct. 10, 1872.

Sheafer, Peter W., Pottsville, Pa. (4). Died March 26, 1891.

Sheppard, William, Drummondville, Province of Quebec, Can. (11). Born in 1783. Died in 1867.

Sherwin, Thomas, Dedham, Mass. (11). Born in Westmoreland, N. H., March 26, 1799. Died in Dedham, Mass., July 23, 1869.

Sill, Elisha N., Cuyahoga Falls, Ohio (6). Born in 1801. Died April 26, 1888.

Silliman, Benjamin, New Haven, Conn. (1). Born in North Stratford, Conn., August 8, 1779. Died in New Haven, Conn., Nov. 22, 1864.

Silliman, Benjamin, New Haven, Conn. (1). Born in New Haven, Conn., Dec. 4, 1816. Died Jan. 14, 1885.

Simpson, Edward, Washington, D. C. (28). Born in New York, N. Y., March 8, 1824. Died in Washington, D. C., Dec. 1, 1888.

Skinner, George, Kalida, Ohio (33).

Skinner, John B., Buffalo, N. Y. (15). Died in 1871.

Slack, J. H., Philadelphia, Pa. (12).

Smith, Charles A., St. Louis, Mo. (27). Died in 1884.

Smith, David P., Springfield, Mass. (29). Born Oct. 1, 1830. Died Dec. 26, 1880.

Smith, Mrs. Erminnie Adelle, Jersey City, N. J. (25). Born April 26, 1836. Died June 9, 1886.

Smith, John Lawrence, Louisville, Ky. (1). Born near Charleston, S. C., Dec. 17, 1818. Died Oct. 12, 1883.

Smith, J. V., Cincinnati, Ohio (5).

Smith, James Young, Providence, R. I. (9). Born in Groton, Conn., Sept. 15, 1809. Died March 26, 1876.

Smith, Lyndon Arnold, Newark, N. J. (9). Born in Haverhill, N. H., November 11, 1795. Died in Newark, N. J., December 15, 1865.

Snell, Ebenezer Strong, Amherst, Mass. (2). Born in North Brookfield, Mass., October 7, 1801. Died in Amherst, Mass., Sept., 1877.

Sparks, Jared, Cambridge, Mass. (2). Born in Willington, Conn., May 10, 1819. Died in Cambridge, Mass., March 14, 1866.

Spinzig, Charles, St. Louis, Mo. (27). Died Jan. 22, 1882.

Squier, Ephraim George, New York, N. Y. (18). Born in Bethlehem, N. Y., June 17, 1821. Died in Brooklyn, N. Y., April 17, 1888.

Stearns, Josiah A., Boston, Mass. (29).

Stearns, Silas, Pensacola, Fla. (28). Died Aug. 2, 1888.

Steele, Joel Dorman, Elmira, N. Y. (33). Born in Lima, N. Y., May 14, 1836. Died May 25, 1886.

Steiner, Lewis H., Baltimore, Md. (7). Born in Frederick City, Md., in 1827. Died in Baltimore, April, 1892.

Stevenson, James, Washington, D. C. (29). Born in Maysville, Ky., Dec. 24, 1840. Died in New York, N. Y., July 25, 1888.

Stimpson, Wm., Chicago, Ill. (12). Born Feb. 14, 1832. Died May 26, 1872.

Stone, Leander, Chicago, Ill. (32). Died April 2, 1888.
Stone, Samuel, Chicago, Ill. (17). Born Dec. 6, 1798. Died May 4, 1876.
St. John, Joseph S., Albany, N. Y. (28). Died Nov. 23, 1882.
Straight, H. H., Chicago, Ill. (25). Died Nov. 17, 1886.
Sturges, George, Chicago, Ill. (37). Born at Putnam, Ohio, May 13, 1838. Died at Lake Geneva, Wis., Aug. 12, 1890.
Sullivan, Algernon Sidney, New York, N. Y. (36). Born April 5, 1826. Died Dec. 4, 1887.
Sullivant, William Starling, Columbus, Ohio (7). Born near Columbus, O., Jan 15, 1803. Died in Columbus, O., April 30, 1873.
Sutton, George, Aurora, Ind. (20). Died June 13, 1886.
Swain, James, Fort Dodge, Iowa (21). Born in 1816. Died in 1877.

Tallmadge, James, New York, N. Y. (1). Born in Stamford, N. Y., Jan. 20, 1778. Died in New York, N. Y., Oct. 8, 1853.
Taylor, Arthur F., Cleveland, Ohio (29). Born Dec. 10, 1853. Died June 28, 1883.
Taylor, Richard Cowling, Philadelphia, Pa. (1). Born in England, Jan. 18, 1789. Died in Philadelphia, Pa., November 26, 1851.
Taylor, Robert N., Tollesboro, Ky. (37). Died Aug. 13, 1888.
Tenney, Sanborn, Williamstown, Mass. (17). Born in January, 1827. Died July 11, 1877.
Teschemacher, James Englehert, Boston, Mass. (1). Born in Nottingham, England, June 11, 1790. Died near Boston, Nov. 9, 1853.
Thompson, A. Remsen, New York, N. Y. (1). Died in Oct., 1879.
Thompson, Alexander, Aurora, N. Y. (1).
Thompson, Charles Oliver, Terre Haute, Ind. (29). Born in East Windsor Hill, Conn., Sept. 25, 1835. Died in Terre Haute, Ind., March 17, 1885.
Thompson, Harvey M., Oakland, Cal. (17).
Thompson, Zadock, Burlington, Vt. (1). Born in Bridgewater, Vt., May 23, 1796. Died in Burlington, Vt, Jan 19, 1856.
Thomson, Henry R., Crawfordsville, Ind. (30). Died in 1884.
Thurber, Isaac, Providence, R. I. (9).
Tileman, John Nicholas, Sandy, Utah (33). Born in Horhun, Denmark, March 28, 1845. Died in Salt Lake City, Utah, Sept. 4, 1888.
Tillman, Samuel Dyer, Jersey City, N. J. (15). Born April, 1815. Died Sept. 4, 1875.
Tobin, Thomas W., Louisville, Ky. (30). Died Aug. 4, 1883.
Todd, Albert, St. Louis, Mo. (27). Born March 4, 1813. Died April 30, 1885.
Tolderoy, James B., Fredericton, N. B. (11).
Torrey, John, New York, N. Y. (1). Born in New York, N. Y., Aug. 15, 1796. Died in New York, March 10, 1873.
Torrey, Joseph, Burlington, Vt. (2). Born in Rowley, Mass., Feb. 2, 1797. Died in Burlington, Vt., Nov. 26, 1867.
Totten, Joseph Gilbert, Washington, D. C. (1). Born in New Haven, Conn., August 23, 1788. Died in Washington, D. C., April 22, 1864.

Townsend, Howard, Albany, N. Y. (10). Born Nov. 22, 1828. Died Jan. 6, 1867.

Townsend, John Kirk, Philadelphia, Pa. (1). Born Aug. 10, 1809. Died Feb. 16, 1851.

Townsend, Robert, Albany, N. Y. (9). Born 1799. Died Aug. 15, 1866.

Trembley, J. B., Oakland, Cal. (17).

Troost, Gerard, Nashville, Tenn. (1). Born in Bois-le-Duc, Holland, March 15, 1776. Died in Nashville, Tenn., Aug. 14, 1850.

Trowbridge, William Pettit, New Haven, Conn. (10). Born in Troy, Mich., in 1828. Died in New Haven, Aug. 12, 1892.

Tuomey, Michael, Tuscaloosa, Ala. (1). Born in Ireland, September 29, 1805. Died in Tuscaloosa, Ala., March 20, 1857.

Tupper, Samuel Y., Charleston, S. C. (38). Died in 1891.

Tweedale, John B., St. Thomas, Can. (35). Born in Ormskirk, Lancashire, Eng., Oct. 16, 1821. Died in St. Thomas, Can., Nov. 18, 1889.

Tyler, Edward R., New Haven, Conn. (1). Born Aug. 3, 1800. Died Sept. 28, 1848.

Tyler, Edward R., Washington. D. C. (31). Died in Washington, March 30, 1891.

Vancleve, John W., Dayton, Ohio (1).

Vanuxem, Lardner, Bristol, Pa. (1). Born in Philadelphia, Pa., July 23, 1792. Died in Bristol, Pa., June 25, 1848.

Vaux, William Sanson, Philadelphia, Pa. (1). Born in Philadelphia, May 19, 1811. Died in Philadelphia, May 5, 1882.

Wadsworth, James Samuel, Genesee, N. Y. (2). Born in Geneseo, N. Y., October 30, 1807. Died near Chancellorville, Va., May 8, 1864.

Wagner, Tobias, Philadelphia, Pa. (9).

Walker, J. R., Bay Saint Louis, Miss. (19). Born Aug. 7, 1830. Died June 22, 1887.

Walker, Joseph, Oxford, N. Y. (10).

Walker, Sears C., Washington, D. C. (1). Born March 28, 1805. Died January 30, 1853.

Walker, Timothy, Cincinnati, Ohio (4). Born in Wilmington, Mass., Dec. 1, 1802. Died in Cincinnati, Ohio, Jan. 15, 1856.

Walling, H. F., Cambridge, Mass. (16). Died Aprill 8, 1888.

Walsh, Benjamin D., Rock Island, Ill. (17). Born in Frome, England, Sept. 21, 1808. Died in Rock Island, Ill., Nov. 18, 1869.

Walton, Joseph J., Philadelphia, Pa. (29). Born in Barnesville, Ohio, Nov. 1, 1855. Died in Philadelphia, Pa., Oct. 11, 1889.

Wanzer, Ira, Brookfield, Conn. (18). Born in New Fairfield, Conn., April 17, 1796. Died in New Milford, Conn., March 5, 1879.

Warnecke, Carl, Montreal, Can. (31). Died May 14, 1886.

Warren, Geo. Washington, Boston, Mass. (18). Died in 1884.

Warren, Gouverneur Kemble, Newport, R. I. (12). Born in Cold Spring N. Y., Jan. 8, 1830. Died in Newport, R. I., Aug. 8, 1882.

Warren, John Collins, Boston, Mass. (1). Born in Boston, Mass., Aug. 1, 1778. Died in Boston, May 4, 1856.

Warren, Samuel D., Boston, Mass. (29). Born in 1817. Died May 11, 1888.

Watertown, Charles, Wakefield, Eng. (1). Born in Wakefield, England. Died in Wakefield, May 26, 1865.

Watkins, Samuel, Nashville, Tenn. (26).

Watson, James Craig, Ann Arbor, Mich. (13). Born in Fingal, Canada, Jan. 28, 1838. Died in Madison, Wis., Nov. 23, 1880.

Watson, Sereno, Cambridge, Mass. (22). Died March 9, 1892, in the 66th year of his age.

Webster, Horace B., Albany, N. Y. (1). Born in 1812. Died Dec. 8, 1843.

Webster, J. W., Cambridge, Mass. (1). Born in 1793. Died Aug. 30, 1850.

Webster, M. H., Albany, N. Y. (1).

Weed, Monroe, Wyoming, N. Y. (6). Died in 1867.

Welch, Mrs. G. O., Lynn, Mass. (21). Died in June, 1882.

Welsh, John, Philadelphia, Pa. (33). Died May, 1886.

Weyman, George W., Pittsburgh, Pa. (6). Born April, 1832. Died July 16, 1864.

Wheatland, Richard H., Salem, Mass. (13). Born July 6, 1830. Died Dec. 21, 1863.

Wheatley, Charles M., Phœnixville, Pa. (1). Died May 6, 1882.

Wheeler, Arthur W., Baltimore, Md. (29). Born in March, 1859. Died Jan. 6, 1881.

Whelldon, William W., Concord, Mass. (13). Born in 1805. Died in Concord, Mass., Jan. 7, 1892.

Whitall, Henry, Camden, N. J. (33).

White, Samuel S., Philadelphia, Pa. (23). Died Dec. 30, 1879.

Whiting, Lewis E., Saratoga Springs, N. Y. (28). Born March 7, 1815. Died Aug. 2, 1882.

Whitman, Edmund B., Cambridge, Mass. (29). Died Sept. 2, 1883.

Whitman, Wm. E., Philadelphia, Pa. (23). Died in 1875.

Whitney, Asa, Philadelphia, Pa. (1). Born Dec. 1, 1791. Died June 4, 1874.

Whittlesey, Charles, Cleveland, Ohio (1). Born in Southington, Conn., Oct. 5, 1808. Died Oct. 18, 1886.

Whittlesey, Charles C., St. Louis, Mo. (11). Died in 1872.

Wight, Orlando W., Detroit, Mich. (34).

Wilber, G. M., Pine Plains, N. Y. (19).

Wilder, Graham, Louisville, Ky. (30). Born July 1, 1843. Died Jan. 16, 1885.

Willard, Emma C. Hart, Troy, N. Y. (15). Born in Berlin, Conn., Feb. 23, 1787. Died in Troy, N. Y., April 15, 1870.

Williams, Frank, Buffalo, N. Y. (25). Died Aug. 13, 1884.

Williams, J. Francis, Salem, N. Y. (31). Died in 1891.

Williams, P. O., Watertown, N. Y. (24).

Williamson, Robert S., San Francisco, Cal. (12). Born in New York about 1825.

Wilson, C. H., Belize, British Honduras (30).

Wilson, Daniel, Toronto, Can. (25). Born in Edinburgh, Scotland. Died in Toronto, Aug., 1892,

Wilson, Mrs. Mary V. C., Mobile, Ala. (37). Born in Morengo County, Ala., Jan. 29, 1840. Died near Tullahoma, Tenn., June 24, 1889.

Wilson, W. C., Carlisle, Pa. (12).

Winchell, Alexander, Ann Arbor, Mich. (3). Born in North East, N. Y., Dec. 31, 1824. Died in Ann Arbor, Mich., Feb. 19, 1891.

Winlock, Joseph, Cambridge, Mass. (5). Born in Shelbyville, Ky., Feb. 6, 1826. Died in Cambridge, Mass., June 11, 1875.

Woerd, Chas. Vander, Waltham, Mass. (29). Born in Leyden, Holland. Oct. 6, 1821. Died near Dagget, Cal., Dec. 29, 1888.

Woodbury, Levi, Portsmouth, N. H. (1). Born in Francistown, N. H., Dec. 22, 1789. Died Sept. 4, 1851.

Woodman, John Smith, Hanover, N. H. (11). Born in Durham, N. H., Sept. 6, 1819. Died in Durham, N. H., May 15, 1871.

Woodward, A. E., Jefferson City, Mo. (39). Died in Montana, Sept. 20, 1891.

Woodward, Joseph Janvier, Washington, D. C. (28). Born in Philadelphia, Pa., Oct. 30, 1833. Died near that city, Aug. 17, 1884.

Worthen, Amos Henry, Springfield, Ill. (5). Born Oct. 31, 1813. Died May 6, 1888.

Worthington, George, New York, N. Y. (36). Died Feb. 1, 1892.

Wright, Elizur, Boston, Mass. (31). Born in South Canaan, Conn., Feb. 12, 1804. Died Nov. 20, 1885.

Wright, Harrison, Wilkes Barre, Pa. (29). Born July 15, 1850. Died Feb. 20, 1885.

Wright, John, Troy, N. Y. (1).

Wyman, Jeffries, Cambridge, Mass. (1). Born in Chelmsford, Mass., Aug. 11, 1814. Died in Bethlehem, N. H., Sept. 4, 1874.

Wyckoff, William Cornelius, New York, N. Y. (20). Born in New York, N. Y., May 28, 1832. Died in Brooklyn, N. Y., May 2, 1888.

Yarnall, M., Washington, D. C. (26). Born in 1817. Died Jan. 27, 1879.

Youmans, Edward Livingston, New York, N. Y. (6). Born in Coeymans, N. Y., June 3, 1821. Died Jan. 18, 1887.

Young, Ira, Hanover, N. H. (1). Born in Lebanon, N. H., May 23, 1801. Died in Hanover, N. H., Sept. 14, 1858.

Zentmayer, Joseph, Philadelphia, Pa. (29). Died, 1887.

# ADDRESS

BY

# ALBERT B. PRESCOTT,

THE RETIRING PRESIDENT OF THE ASSOCIATION.

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## *THE IMMEDIATE WORK IN CHEMICAL SCIENCE.*

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A DIVISION of science has a work of its own to do, a work that well might be done for its own sake, and still more must be done in payment of what is due to the other divisions. Each section of our Association has its just task, and fidelity to this is an obligation to all the sections. Those engaged in any labor of science owe a debt to the world at large, and can be called to give an account of what they are doing, and what they have to do, that the truth may be shown on all sides.

If it be in my power to make the annual address of this meeting of any service at all to you who hear it — in your loyalty to the Association—I would bring before you some account of the work that is wanted in the science of chemistry. Of what the chemists have done in the past the arts of industry speak more plainly than the words of any address. Of what chemists may do in the future it would be quite in vain that I should venture to predict. But of the nature of the work that is waiting in the chemical world at the present time I desire to say what I can, and I desire to speak in the interests of science in general. The interests of science, I am well assured, cannot be held indifferent to the interests of the public at large.

It is not a small task, to find out how the matter of the universe is made. The task is hard, not because of the great quantity in which matter exists, nor by reason of the multiplicity of the kinds and compounds of matter, but rather from the obscurity under which the actual composition of matter is hidden from man. The physicists reach a conclusion that matter is an array of molecules, little things, not so large as a millionth of a millimeter in size, and the formation of these they leave to the work of the chemists. The smallest objects dealt with in science, their most distinct activities become known only by the widest exercise of inductive reason.

The realm of chemical action, the world within the molecules of matter, the abode of the chemical atoms, is indeed a new world and but little known. The speculative atoms of the ancients, mere mechanical divisions, prefiguring the molecules of modern science, yet gave no sign of the chemical atoms of this century, nor any account of what happens in a chemical change. A new field of knowledge was opened in 1774 by the discovery of oxygen, and entered upon in 1804 by the publications of Dalton, a region more remote and more difficult of access than was the unknown continent toward which Christopher Columbus set his sails three centuries earlier. The world within molecules has been open for only a hundred years. The sixteenth century was not long enough for an exploration of the continent of America, and the nineteenth has not been long enough for the undertaking of the chemists. When four centuries of search shall have been made in the world of chemical formation, then science should be ready to meet a congress of nations, to rejoice with the chemist upon the issue of his task.

It is well known that chemical labor has not been barren of returns. The products of chemical action, numbering thousands of thousands, have been sifted and measured and weighed. If you ask what happens in a common chemical change you can obtain direct answers. When coal burns in the air, how much oxygen is used up, can be stated with a degree of exactness true to the first decimal of mass, perhaps to the second, yet questionable in the third. How much carbonic acid is made can be told in weight and in volume with approaching exactness. How much heat this chemical action is worth, how much light, how much electro-motive force, what train-load of cars it can carry, how long it can make certain wheels go round,— for these questions chemists and physicists are ready. With how many metals carbonic acid will unite, how many ethers it can make into carbonates, into what classes of molecules a certain larger fragment of carbonic acid can be formed, the incomplete records of these things already run through a great many volumes. These carboxylic bodies are open to productive studies, stimulated by various sorts of inquiry and demands of life. Such have been the gatherings of research. They have been slowly drawn into order, more slowly interpreted in meaning. The advance has been constant, deliberate, sometimes in doubt, always persisting and gradually gaining firmer ground. So chemistry has reached *the period of definition*. Its guiding theory has come to be realized.

"The atomic theory" has more and more plainly appeared to be the central and vital truth of chemical science. As a working hypothesis it has directed abstruse research through difficult ways to open accomplishment in vivid reality. As a system of knowledge, it has more than kept pace with the rate of invention. As a philosophy, it is in touch with profound truth in physics, in the mineral kingdom, and in the functions of living bodies. As a language it has been a necessity of man in dealing with chemical events. Something might have been done, no doubt, without it, had it been possible to keep it out of the chemical mind. But with a knowledge of the primary elements of matter, as held at the beginning of this century, some theory of chemical atoms was inevitable. And whatever theory might have been adapted, its use in investigation would have drawn it with a certainty into the essential features of the theory now established. It states the constitution of matter in terms that stand for things as they are made. The mathematician may choose the ratio of numerical notation, whether the ratio of ten or some other. But the chemist must find existing ratios of atomic and molecular mass, with such degree of exactness as he can attain. Chemical notation, the index of the atomic system, is imperfect, as science is incomplete. However defective, it is the resultant of a multitude of facts. The atomic theory has come to be more than facile language, more than lucid classification, more than working hypothesis, it is *the definition of the known truth in the existence of matter*.

The chemical atom is known, however, for what it does, rather than for what it is. It is known as a center of action, a factor of influence, an agent of power. It is identified by its responses, and measured by its energies. Concealed as it is, each atom has given proof of its own part in the structure of a molecule. Proofs of position, not in space but in action, as related to other atoms, have been obtained by a multitude of workers with the greatest advantage. The arrangement of the atoms in space, however, is another and later question, not involved in the general studies of structure. But even this question has arisen upon its own chemical evidences, for certain bodies, so that "the configuration" of the molecule has become an object of active research.

Known for what it does, the atom is not clearly known for what it is. Chemists, at any rate, are concerned mainly with what can be made out of atoms, not with what atoms can be made of. Whatever they are, and by whatever force or motion it is that they unite with each other, we define them by their effects. Through their effects they are classified in the rank and file of the periodic system. The physicists, however, do not stop short of the philosophical study of the atom itself. As a vibratory body its movements have been under mathematical calculations; as a vortex ring its pulsations have been assumed to agree with its combining power. As an operating magnet its interaction with other like magnets has been predicated as the method of valence. There are, as I am directly assured, physicists of penetration and prudence now looking with confidence to studies of the magnetic relations of atoms to each other.[1] Moreover, another company of workers, the chemists of geometric isomerism, assume a configuration of the atoms, in accord with that of the molecule.

The stimulating truth of the atomic constitution of the molecule, a great truth in elastic touch with all science, excites numerous hypotheses, which, however profitable they may be, are to be stoutly held at a distance from the truth itself. Such are the hypotheses of molecular aggregation into crystals and other mineral forms. Such are the biological theories of molecules polymerizing into cells, and of vitality as a chemical property of the molecule. Such are the questions of the nature of atoms, and the genesis of the elements as they are now known, questions on the border of metaphysics. Let all these be held distinct from the primary law of the atomic constitution of simple molecules in gaseous bodies, an essential principle in an exact science. The chemist should have the

[1] "The results of molecular physics point unmistakably to the atom as a magnet, in its chemical activities."—A. E. Dolbear, in a personal communication.

comfortable assurance, every day, as he plies his balance of precision, that the atom-made molecules are there, in their several ratios of quantity, however many unsettled questions may lie around about them. Knowledge of molecular structure makes chemistry a science, nourishing to the reason, giving dominion over matter, for beneficence to life.

Every chemical pursuit receives strength from every advance in the knowledge of the molecule. And to this knowledge, none the less, every chemical pursuit contributes. The analysis of a mineral, whether done for economic ends or not, may furnish a distinct contribution toward atomic valence. The further examination of steel in the cables of a suspension bridge is liable to lead to unexpected evidence upon polymeric unions. Rothamsted farm, where ten years is not a long time for the holding of an experiment, yields to us a classic history of the behavior of nitrogen, a history from which we correct our theories. The analysis of butter for its substitutes has done something to set us right upon the structure of the glycerides. Clinical inspection of the functions of the living body fain finds a record of molecular transformations too difficult for the laboratory. The efforts of pharmaceutical manufacture stimulate new orders of chemical combination. The revision of the pharmacopœia every ten years points out a humiliating number of scattered errors in the published constants on which science depends. The duty of the engineer, in his scrutiny of the quality of lubricating oils, brings a more critical inquiry into the laws of molecular movement. There is not time to mention the many professions and pursuits of *men who contribute toward the principles of chemistry* and hold a share therein. If it be the part of pure science to find the law of action in nature, it is the part of applied science both to contribute facts and to put theory to the larger proof. In the words of one who has placed industry in the greatest of its debts to philosophic research, W. H. Perkin, "There is no chasm between pure and applied science, they do not even stand side by side, but are linked together." So in all branches of chemistry, whether it be termed applied or not, the best workers are the most strongly bound as one, in their dependence upon what is known of the structure of the molecule.

Studies of structure were never before so inviting. In this direction and in that especial opportunities appear. Moreover the actual worker here and there breaks into unexpected paths of promise. Certainly the sugar group is presenting to the chemist an open way from simple alcohols on through to the cell substances of the vegetable world. And nothing anywhere could be more suggestive than the extremely simple unions of nitrogen lately discovered. They are likely to elucidate linkings of this element in great classes of carbon compounds, all significant in general chemistry. Then certain comparative studies have new attractions. As halogens have been upon trial side by side with each other, so for instance, silicon must be put through its paces with carbon, and phosphorus with nitrogen. Presently, also, the limits of molecular mass, in polymers and in unions with water, are to be nearer approached from the chemical side, as well as from the side of physics, in that attractive but perplexing border ground between affinity and the states of aggregation.

Such is the extent and such the diversity of chemical labor at present that every man must put limits to the range of his study. The members of a society or section of chemistry, coming together to hear each other's researches, are better able, for the most part, to listen for instruction than for criticism. Still less prepared for hasty judgment are those who do not come together in societies at all. Even men of eminent learning must omit large parts of the subject, if it be permitted to speak of chemistry as a single subject. These considerations admonish us to be liberal. When metallurgical chemistry cultivates skepticism as to the work upon atomic closed chains, it is a culture not the most liberal. When a devotee of organic synthesis puts a low value upon analytic work, he takes a very narrow view of chemical studies. When the chemist, who is in educational service, disparages investigations done in industrial service, he exercises a pitiful brevity of wisdom.

The pride of pure science is justified in this, that its truth is for the nurture of man. And the ambition of industrial art is honored in this, its skill gives strength to man. It is the obligation of science to bring the resources of the earth, its vegetation and its animal life, into the full service of man, making the knowledge of creation a rich portion of his inheritance, in mind and estate, in reason and in conduct, for life present and life to come. To know creation is to be taught of God.

I have spoken of the century of beginning chemical labor, and have referred to the divisions and specialties of chemical study. What can I say of the means of uniting the earlier and later years of the past, as well as the separated pursuits of the present, in one mobile working force? Societies of science are among these means, and it becomes us to magnify their office. For them, however, all that we can do is worth more than all we can say. And there are other means, even more effective than associations. Most necessary of all the means of unification in science is the use of its literature.

It is by published communication that the worker is enabled to begin, not where the first investigation began, but where the last one left off. The enthusiast who lacks the patience to consult books, presuming to start anew all by himself in science, has need to get on faster than Antoine L. Lavoisier did when he began, an associate of the French Academy in 1768. He of immortal memory, after fifteen eventful years of momentous labor, reached only such a combustion of hydrogen as makes a very simple class experiment at present. But however early in chemical discovery, Lavoisier availed himself of contemporaries. They found oxygen, he learned oxidation: one great man was not enough, in 1774, both to reveal this element and show what part it takes in the formation of matter. The honor of Lavoisier is by no means the less that he used the results of others, it might have been the more had he given their results a more explicit mention. Men of the largest original power make the most of the results of other men. Discoverers do not neglect previous achievement, however it may appear in biography. The masters of science are under the limitations of their age. Had Joseph Priestley lived in the seventeenth century he had not discovered oxygen. Had August Kekulé worked in the period of Berzelius, some other man would have set forth the closed chain of carbon combination, and Kekulé, we may be sure, would have done something else to clarify chemistry. Such being the limitations of the masters, what contributions can be expected in this age from a worker who is without the literature of his subject?

In many a town some solitary thinker is toiling intensely over some self-imposed problem, devoting to it such sincerity and strength as should be of real service, while still he obtains no recognition. Working without books, unaware of memoirs on the theme he loves, he tries the task of many with the strength of one. Such as he sometimes send communications to this association. An earnest worker, his utter isolation is quite enough to convert him into a crank. To every solitary investigator I should desire to say, get to a library of your subject, learn how to use its literature, and possess yourself of what there is on the theme of your choice, or else determine to give it up altogether. You may get on very well without college laboratories, you can survive it if unable to reach the meetings of men of learning, you can do without the counsel of an authority, but you can hardly be a contributor in science except you gain the use of its literature.

First in importance to the investigator are the original memoirs of previous investigators. The chemical determinations of the century have been reported by their authors in the periodicals. The serials of the years, the continuous living repositories of all chemistry, at once the oldest and the latest of its publications, these must be accessible to the worker who would add to this science. A library for research is voluminous, and portions of it are said to be scarce, nevertheless it ought to be largely supplied. The laboratory itself is not more important than the library of science. In the public libraries of our cities, in all colleges now being established, the original literature of science ought to be planted. It is a wholesome literature, at once a stimulant and a corrective of that impulse to discovery that is frequent among the people of this country. That a good deal of it is in foreign languages is hardly a disadvantage; there ought to be some exercise for the modern tongues that even the public high schools are teaching. That the sets of standard journals are getting out of print is a somewhat infirm objection. They have no right to be out of print in these days when they give us twenty pages of blanket newspaper at breakfast, and offer us Scott's novels in full for less than the cost of a day's entertainment. As for the limited editions of the old sets, until reproduced by new types, they may be multiplied through photographic methods. When there is a due demand for the original literature of chemistry, a demand in accord with the prospective need for its use, the supply will come, let us believe, more nearly within the means of those who require it than it now does.

What I have said of the literature of one science can be said, in the main, of the literature of the other sciences. And other things ought to be said, of what is wanted to make the literature of science more accessible to consulting readers. *A great deal of indexing is wanted.* Systematic bibliography, both of previous and of current literature, would add a third to the productive power of a large number of workers. It would promote common acquaintance with the original communications of research, and a general demand for the serial sets. Topical bibliographies are of great service. In this regard I desire to ask attention to the annual reports of the committee on Indexing Chemical Literature, in this association for nine years past, as well to recent systematic undertakings in geology, and like movements in zoology and other sciences. Also to the Index Medicus, as a continuous bibliography of current professional literature.

Societies and institutions of science may well act as patrons to the bibliography of research, the importance of which has been recognized by the fathers of this Association. In 1855, Joseph Henry, then a past president of this body, memorialized the British Association for coöperation in bibliography, offering that aid of the Smithsonian Institution which has so often been afforded to publications of special service. The British Association appointed a committee, who reported in 1857, after which the undertaking was proposed to the Royal Society. The Royal Society made an appeal to her Majesty's government, and obtained the necessary stipend. Such was the inception of the Royal Society Catalogue of scientific papers of this century, in eight quarto volumes, as issued in 1867 and 1877. Seriously curtailed from the generous plan of the committee who proposed it, limited to the single feature of an index of authors, it is nevertheless of great help in literary search. Before any list of papers, however, we must place a list of the serials that contain them, as registered by an active member of this Association, an instance of industry and critical judgment. I refer to the well-known catalogue of scientific and technical periodicals, of about five thousand numbers, in publication from 1665 to 1882, together with the catalogue of chemical periodicals by the same author.[1]

Allied to the much needed service in bibliography, is the service in compilation of the Constants of Nature. In the preface of his dictionary of solubilities, in 1856, Professor Storer said "that chemical science itself might gain many advantages if all known facts regarding solubility were gathered from their widely scattered original sources into one special comprehensive work." That the time

[1] Bolton's Catalogue of Scientific and Technical Periodicals (1885: Smithsonian) omits the serials of the societies, as these are the subject of Scudder's Catalogue of Scientific Serials (1879: Harvard Univ.). On the contrary Bolton's Catalogue of Chemical Periodicals (1885: N. Y. Acad. Sci.) includes the publications of societies as well as other serials. Chemical technology is also represented in the last named work.

of the philosophical study of solution was near at hand has been verified by recent extended monographs on this subject. In like manner Thomas Carnelley in England, and early and repeatedly our own Professor Clarke in the United States,[1] bringing multitudes of scattered results into coördination, have augmented the powers of chemical service.

What bibliography does for research, the Handwörterbuch does for education, and for technology. It makes science wieldy to the student, the teacher, and the artisan. The chief dictionaries of science, those of encyclopedic scope, ought to be provided generally in public libraries, as well as in the libraries of all high schools.[2] The science classes in preparatory schools should make an acquaintance with scientific literature in this form. If scholars be assigned exercises which compel reference reading, they will gain a beginning of that accomplishment too often neglected, even in college, how to use books.

The library is a necessity of the laboratory. Indeed, there is much in common between what is called the laboratory method, and what might be called the library method, in college training. The educational laboratory was instituted by chemistry, first taking form under Liebig at Giessen only about fifty years ago. Experimental study has been adopted in one subject after another, until, now, the "laboratory method" is advocated in language and literature, in philosophy and law. It is to be hoped that chemistry will not fall behind in the later applications of "the new education" in which she took so early a part.

The advancement of chemical science is not confined to discovery, nor to education, nor to economic use. All of those interests it should embrace. To disparage one of them is injurious to the others. Indeed, they ought to have equal support. It would be idle to inquire into their respective advantages. This much, however, is evident enough, chemical work is extensive and there is immediate want of it.

[1] The service of compilation of this character is again indicated by this extract from Clarke's introduction to the first edition of his "Constants" (1873): "While engaged upon the study of some interesting points in theoretical chemistry, the compiler of the following tables had occasion to make frequent reference to the then existing lists of specific gravities. None of these, however, were complete enough. . . ."

[2] The statistics of school libraries in the United States are very meagre. the expenditures for them being included with that for apparatus. For libraries and apparatus of all common schools, both primary and secondary, the annual expenditure is set at $987,048, which is about seven-tenths of one per cent of the total expenditure for these schools.

Various other branches of science are held back by the delay of chemistry. Many of the material resources of the world wait upon its progress. In the century just before us the demands upon the chemist are to be much greater than they have been. All the interests of life are calling for better chemical information. Men are wanting the truth. The biologist on the one hand, and the geologist on the other, are shaming us with interrogatories that ought to be answered. Philosophy lingers for the results of molecular inquiry. Moreover the people are asking direct questions about the food they are to eat, or not to eat, asking more in a day than the analyst is able to answer in a month. The nutritive sources of bodily power are not safe, in the midst of the reckless activity of commerce, unless a chemical safeguard be kept, a guard who must the better prepare himself for his duty.

Now if the people at large can but gain a more true estimation of the bearing of chemical knowledge, and of the extent of the chemical undertaking, they will more liberally supply the sinews of thorough-going toil. It must be more widely understood that achievements of science, such as have already multiplied the hands of industry, do not come by chances of invention, nor by surprises of genius. It must be learned of these things that they come by breadth of study, by patience in experiment, and by the slow accumulations of numberless workers. And it must be made to appear that the downright labor of science actually depends upon means of daily subsistence. It must be brought home to men of affairs, that laboratories of seclusion with delicate apparatus, that libraries, such as bring all workers together in effect, that these really cost something in the same dollars by which the products of industrial science are measured. Statistics of chemical industry are often used to give point to the claims of science. For instance it can be said that this country, not making enough chemical wood pulp, has paid over a million dollars a year for its importation. That Great Britain pays twelve millions dollars a year for artificial fertilizers, from without. That coal tar is no longer counted a by-product, having risen in its value to a par with coal gas. But these instances, as striking as numerous others, still tend to divert attention from the more general service of chemistry as it should be known in all the economies of civilization.

It is not for me to say what supplies are wanted for the work of chemists. These wants are stated, in quite definite terms, by a sufficient number of those who can speak for themselves. But if my voice could reach those who hold the supplies, I would plead a most considerate hearing of all chemical requisitions, and that a strong and generous policy may in all cases prevail in their behalf.

If any event of the year is able to compel the attention of the world to the interests of research, it must be the notable close of that life of fifty years of enlarged chemical labor, announced from Berlin a few months ago. When thirty years of age, August Wilhelm von Hofmann, a native of Giessen and a pupil of Liebig, was called to work in London. Taking hold of the organic derivatives of ammonia, and presently adopting the new discoveries of Wurtz, he began those masterly contributions that appear to have been so many distinct steps toward a chemistry of nitrogen, such as industry and agriculture and medicine have thriven upon. In 1850 he opened a memoir in the philosophical transactions with these words "the light now begins to dawn upon the chaos of collected facts." Since that time the coal tar industry has risen and matured, medicine has learned to measure the treatment of disease, and agriculture to estimate the fertility of the earth. It seems impossible that so late as March of the present year, he was still sending his papers to the journals. If we could say something of what he has done we could say nothing of what he has caused others to do. And yet, let it be heard in these United States, without such a generous policy of expenditure for science as gave to Dr. Hofmann his training in Giessen, or brought him to London in 1848, or built for him laboratories in Bonn and Berlin, without such *provision by the state*, the fruits of his service would have been lost to the world. Aye, and for want of a like broad and prudent provision for research with higher education, in this country, other men of great love for science and great power of investigation every year fail of their rightful career for the service of mankind.

For the prosecution of research, in the larger questions now before us, no training within the limitations of human life can be too broad or too deep. No provision of revenue, so far as of real use to science, can be too liberal. The truest investigation is the most prudent expenditure that can be made.

In respect to the support that is wanted for work in science, I have reason for speaking with confidence. If I go beyond the subject with which I began I do not go beyond the warrant of the Association. This body has lately defined what its members may say, by creating a committee to receive endowments for the support of research.

There are men and women who have been so far rewarded, that great means of progress are in their hands, to be vigorously held for the best advantage. Strength is required to use large means, as well as to accumulate them. It is inevitable to wealth, that it shall be put to some sort of use, for without investment it dies. By scattered investment wealth loses personal force. The American Association, in the conservative interests of learning, proposes certain effective investments in science. If it be not given to every plodding worker to be a promoter of discovery, such at all events is the privilege of wealth, under the authority of this Association. If it be not the good fortune of every investigator to reach knowledge that is new, there are, every year, in every section of this body, workers of whom it is clear that they would reach some discovery of merit, if only the means of work could be granted them. Whosoever supplies the means fairly deserves and will receive a share in the results. It is quite with justice that the name of Elizabeth Thompson, the first of the patrons, has been Associated with some twenty-one modest determinations of merit recognized by this Association.

"To procure for the labors of scientific men increased facilities" is one of the constitutional objects of this body. It is time for effectiveness towards this object. The Association has established its character for sound judgment, for good working organization, and for representative public interest. It has earned its responsibility as *the American trustee of undertakings in science.*

"To give a stronger . . . impulse . . . to scientific research" is another declaration of what we ought to do. To this end larger endowments are necessary. And it will be strange if some clear-seeing man or woman does not put ten thousand dollars, or some multiple of it, into the charge of this body for some searching experimental inquiry now waiting for the material aid. The committee upon endowment is ready for consultation upon all required details.

"To give . . . more systematic direction to scientific research" is likewise stated as one of our objects. To this intent the organization of sections affords opportunities not surpassed. The discussions upon scientific papers give rise to a concord of competent opinions as to the direction of immediate work. And arrangements providing in advance for the discussion of vital questions, as formally moved at the last meeting, will in one way or another point out to suitable persons such lines of labor as will indeed give systematic direction to research.

In conclusion I may mention another, the most happy of the duties of the American Association. It is to give the hand of hospitable fellowship to the several societies who year by year gather with us upon the same ground. Comrades in labor and in refreshment, their efforts reinforce us, their faces brighten our way. May they join us more and more in the companionship that sweetens the severity of art. A meeting of good workers is a remembrance of pleasure, giving its zest to the aims of the year.

## SECTION A.

# MATHEMATICS AND ASTRONOMY.

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## ADDRESS

BY

# J. R. EASTMAN,

VICE PRESIDENT, SECTION A.

## *THE NEGLECTED FIELD OF FUNDAMENTAL ASTRONOMY.*

If a comparison were instituted between the position of the modern astronomer and that of his prototype, on the plains of Chaldea, it would not be altogether to the disadvantage of the ancient student of the heavens. He stood at the gateway of the unexplored Uranian mysteries, unfettered by the dogmatic theories of a long line of predecessors. From his own imagination he constructed hypotheses and theories, with no feeling of uncertainty about the priority of invention and with little anxiety concerning the agreement of theory and observation. The modern questions that distract the astronomical world had no place among the thoughts that disturbed the tranquillity of his soul. He had not reached that critical epoch when he must choose between the "old" and the "new" astronomy; and he was free from the harassing perplexity that besets the luckless astronomer of this age who seeks to learn the mysteries of the moon's motion, or strives to formulate the cause and the law of the variation in the terrestrial latitude. The iniquitous behavior of the astronomical clock and level, combined with the possible, but unknown, influences of temperature, were not then in league to vex his waking hours and fill his dreams with illusory solutions that ever floated just beyond his grasp. He was not obliged to search the ancient records in musty volumes and strain the limits of conjecture in the interpretation of careless observations and imperfect memoranda :—in short, he was a happy man, free to work in any direction, and not liable to be called upon from time to time to amuse or to instruct his fellows, or even to weary them, with prosy discourse on his own work or a stale résumé of astronomical progress.

Unfortunately for us, we live in an age where astronomy is no longer a simple subject, stimu'ating the imagination by the nightly display of stellar and planetary glories and involving in its study only the elements of geometrical analysis. Within the last fifty years the science has been separated into many divisions; and within a few years several of these branches have assumed new phases. As a result of this continued division, the range of study and investigation has spread beyond the efficient grasp of any individual and specialists are rising up in all directions.

It has been the custom for the presiding officer of this section to present, on the first day of the annual session, an address setting forth either the progress in general astronomy or in some branch of the science, or the history or development of some department of mathematics; each confining himself to his own special branch of scientific work.

It has seemed to me that a formal statement, to this section, of the general progress of astronomy within the last year or the last decade would be to lay before you a mass of data with which you are already familiar. This view of the case has led me to attempt the presentation of the importance of one branch of astronomical work, in which for several years I have taken a deep personal interest, and which, owing to the present tendency towards specialization, is likely to suffer from serious neglect.

It is not many years since we first heard of the distinction between the "old" and the "new" astronomy, but in the comparatively short interval since those terms were first used, the scope of Physics has so expanded in all directions and so adapted itself to its new surroundings, that we find it, in one department at least, casting aside its former title and masquerading under the name of Astronomy. That this departure has quickened the zeal of many students, stimulated the development of numerous and valuable modes of research and resulted in grand and important discoveries is one of the most gratifying scientific facts of this epoch. The direction of this new movement has followed rigorously the line of least resistance. Except in rare instances, that line of work which promises the quickest returns, in the proper form for publication, is most attractive to the young student of Physics and Astronomy, and the comparatively inexpensive apparatus required for the simpler astro-physical work is apt to lead him in that direction. The new and important changes that have been wrought within a few years in the methods of teaching and in the laboratory work in Physics, together with the apparent ease with which an account of a few hours' labor with the spectroscope or camera may be spread attractively over several printed pages, have doubtless had their influence in leading the candidates for honors into the new fields of astrophysical research.

The advance in the development of methods of research and the improvements in apparatus are so rapid, while the field is so broad and increasing, that constant vigilance is necessary to keep even in touch with the progress of the "new" astronomy. One of the most striking examples of the achievements in this new line of work has resulted, from a skilful combination of the spectroscope and the camera, in the determination of stellar motion in the line of sight with a remarkable linear exactness.

The limits of this address would scarcely suffice simply to name the problems now under discussion, by the more modern methods, without essaying even a cursory review of their importance or their bearing on current scientific investigation;— and yet, from the true astronomical point of view, all these questions are at least secondary to the fundamental problems of finding the true position of the solar system in the stellar universe and determining the relative positions and motions of those stars that, within the range of telescopic vision, compose that universe.

To this latter phase of our science I ask your attention for a few minutes. These problems still lie at the foundation of the "old" astronomy and cannot be relegated to the limbo of useless rubbish or to the museum of curious relics, not even to make room for the newborn astro-physics. On this foundation must rest every astronomical superstructure that hopes to stand the tests of time and of observation, and the precision of the future science depends rigorously upon the accuracy with which this groundwork is laid.

This work was begun in the sixteenth century but, in spite of all the improvements in apparatus and in methods of analysis and research, a really satisfactory result has not yet been reached.

There is no more fascinating phase of the evolution of human thought and skill in the adaptation of means to ends than is found in the development of the mathematical and instrumental means for the determination of the positions and motions of the bodies included in the solar system. Accuracy in astronomical methods and results did not exist, even approximately, until after the revival of practical astronomy in Europe about the beginning of the sixteenth century; and, before the end of that period, the crude instruments of the early astronomers reached their highest perfection in the hands of the skilful genius of Uraniborg.

The invention of the telescope, the application of the pendulum to clocks, the invention of the micrometer, the combination of the telescope with the divided arc of a circle, the invention of the transit circle by Roemer, with many improvements in minor apparatus distinctly stamp the seventeenth century as a remarkable period of preparation for the achievements of the next century.

From the standpoint of the modern mechanician the instruments at the Greenwich Observatory, in Bradley's time, were very imperfect in design and construction; and yet, on the observations obtained by his skill and perseverance, depends the whole structure of modern fundamental astronomy. The use of the quadrant reached its highest excellence under Bradley's management.

The next advance, the real work with divided circles, began at Greenwich in 1811, under the direction of Pond. Since that epoch, theory and observation have held a nearly even course in the friendly race toward that elusive goal, perfection; and the end is not yet. A careful, but independent, determination of the relative right ascensions of the principal stars, supplemented by a rigorous adjustment of such positions with regard to the equinoctial points: and a similar determination of the relative zenith or polar distance of the same bodies, finally referred and adjusted to the equator or the pole,—seem in this brief statement to be, at least, simple problems. If, however, we examine the conditions in detail, the simplicity may not appear so evident; and this characteristic may prove to be one reason why this important branch of astronomical research is now so generally neglected.

In the first place, it must be understood that such an investigation cannot be completed in a few months. At least *two* and preferably *three* years work in observing are necessary to secure good results. Skilled observers, and not more than two with the same instrument, are absolutely necessary. Such work cannot be confided to students or beginners in the art of observing, or to observers who have acquired the habit of anticipating the transit of a star. The telescope and the circles, the objective and the micrometer, the clock and the level must be of the best quality, for imperfections in any of these essentials render the best results impossible. A thoroughly good astronomical clock is the rarest instrument in the astronomer's collection. It is not sufficient that a clock should have a uniform daily rate, the rate should be uniform for any number of minor periods during the twenty-four hours. The absolute personal error in observing transits should be determined at least twice a week, and when it is not well established it should be found every day. The level error should be found every two hours and the greatest care should be exercised in handling this important instrument. The division marks should not be etched on the level tube unless the values of the divisions are frequently examined, for, sooner or later, such tubes become deformed on account of the broken surface and are then worthless.

In the determination of zenith distances the effect of refraction plays such an important part that no work can rightly claim to be fundamental until the local refraction has been carefully investigated and special corrections to the standard tables, if necessary, have been deduced for each observing station. The ordinary mode of observing temperatures is quite inadequate to the importance of the phenomena. These observations should be made as near as possible in the mass of air through which the objective of the telescope is moved and also in the opening in the roof and the sides of the observing room where the outside air comes in contact with that in the building. The thermometers should all be mounted so that they may be whirled in that portion of the air where the temperature is desired, and they should be tested at least once a year to determine the change in the position of the zero of the scale. But a complete list of the things to be done, and of the errors to be avoided, are too voluminous for this occasion and are not necessary to show the complex character of the problem;—the suggestions, already made, must suffice.

For many years an immense number of observations of the larger or the so-called standard stars have been made at the principal observatories, for different purposes and with varying degrees of accuracy, but it is not certain that the work of the last thirty years, with all the advantages of improved apparatus, has resulted in more exact determinations of even the *relative* right ascensions of such stars. There can be no doubt that the chronographic registration of star transits has given more accurate results for the smaller stars, but I think it is equally true that, in the case of first and second magnitude stars, at least, no improvement has been made in accuracy.

With double threads it is possible to observe the zenith distances of such stars with a fair degree of precision, because the operation is one of comparative deliberation and the centre of the mass of light can be placed midway between the threads with little difficulty. But the attempt to note with a chronograph key, the instant when a swiftly moving and irregular mass of light, like *α* Canis Majoris or *α* Lyræ, is bisected by a transit thread, is an operation that rises but little above the level of ordinary guesswork. Transits of first and second magnitude stars cannot be observed with an objective of more than four inches aperture, with the desired accuracy, unless the apparent magnitude is reduced, by means of screens, to that of a fourth or fifth magnitude star. It is necessary in this connection to avoid confounding the methods employed in the observations of the bodies of the solar system with those for obtaining fundamental places of the stars. The observations of the Sun, Moon, Mercury and Venus with a transit circle are, from the unavoidable conditions, necessarily uncertain to a degree even beyond the probable error involved in the observations of the large stars. In spite of these unfavorable conditions, however, the continued observations of these bodies at the principal observatories, for many years, have produced the most valuable results even when the work on the standard stars, on which their results depend, has no claim, whatever, to a fundamental character.

In geographic exploration the first endeavor is to secure approximate positions of salient points from a rapid reconnoissance. This is followed by more careful work fixing the observing stations with that degree of precision which insures good results. Finally, the highest qualities of skill and science are combined to exhaust all available means to reach the greatest attainable accuracy. In the exploration of the heavens, the first two of these steps have already been taken, and most of the stars of the larger magnitudes have been so well observed, that the accuracy of their positions is not only far higher than is required by the greatest skill of the navigator, but it is equal to all the demands of ordinary practical work. It is the next step which challenges the skill of the mechanician, the observer and the computer; and astronomers cannot rest at ease until all known resources have been exhausted in the attempt to reach the best results. It is not a very difficult matter to fix the position of stars within a range, in the individual observations, of three or four seconds of arc, but that degree of accuracy is not sufficient for the more exact problems of astronomy, and it falls far short of what is required in the important discussions of solar and stellar motions.

Bradley's observations furnished the data for Bessel's Fundamenta Astronomiæ and many astronomers have since attempted by rereductions to obtain improved positions for Bradley's stars. The value of these observations in the development of modern astronomy can hardly be exaggerated. Their importance in the determination of stellar proper motions increases with the lapse of time; and yet, the accuracy of the original observations was far inferior to that obtained in ordinary routine work with modern methods and improved instruments.

Fundamental Catalogues of stars have notably increased since the Fundamenta Astronomiæ, but the demand has not yet been satisfied. The catalogues of declinations or north-polar distances are more numerous than those of right ascension, evidently because, for many reasons, independent declinations are more readily determined.

There is probably no collection of the right ascension of the large stars that has attained, or justly deserved, a higher reputation than the Pulkowa Catalogue. The observations on which this catalogue is founded were made by Schweizer, Fuss, Lindhagen and Wagner, at the Pulkowa observatory between 1842 and 1853. The observations were reduced by the several observers, thoroughly discussed by Wagner and published in 1869. Only one observer was employed at any period. As these results have received high praise for their accuracy and for their freedom from systematic errors, it may be of some interest to consider briefly, and in a general way, the character of the data on which the results depend.

The objective of the transit instrument with which these observations were made, had a focal length of 8 feet and 6 inches and a diameter of 5.85 inches. It was so constructed that the ocular and the objective could be interchanged. It was also reversible, and a part of the observations were made with the clamp east and the remainder with the clamp west. This construction permitted the observations to be made under four different sets of conditions, and for that reason the observed right ascensions of each star were arranged, for facility of discussion, in four separate groups.

An examination of the results in each group discloses some interesting facts that are worth considering somewhat in detail. The whole number of stars in the catalogue that are reckoned as standard stars, and are south of 70° north declination, is 365. Of this number seventy per cent have a range, in the individual results, in at least one of the four groups, of two-tenths, or more, of a second of time. This range is between $0^s.20$ and $0^s.29$ for 142 stars; between $0^s.30$ and $0^s.39$ for 92 stars; between $0^s.40$ and $0^s.49$ for 15 stars, and $0^s.50$ or more for 6 stars. The mean range for the 255 stars is $0^s.297$. In general, the accordance between the individual results is quite good but the discordance just mentioned sometimes occurs more than once in the collected observations of the same star, and these doubtful data have been used in deducing the standard places given in the catalogue. It is not necessary to look for minor discrepancies, for enough of appreciable magnitude have been cited already to warrant the conclusion that better observing can, and ought to be done with modern instruments and that the needs of astronomical science to-day demand a more comprehensive, and a more accurate, standard catalogue of right ascensions.

These remarks must not be interpreted as unfavorable criticism of the Pulkowa catalogue, by far the best work of its period, but they are made simply to call attention to the fact, that the present state of stellar astronomy and the direction which the investigations of the immediate future are likely to take, plainly require the most accurate fundamental catalogue of the standard stars that modern instruments and appliances, modern methods and the most skilful observers can produce. All of these conditions are essential and they must be carefully coördinated to obtain the desired results.

It must be plain to every astronomer that the needed fundamental catalogue must be deduced from new observations. The reduction and discussion of old observations of doubtful quality are a waste of time and energy. Under existing circumstances the greatest weight must be given to the observations. Neither amount of labor nor skill in computation can derive results of the desired accuracy from careless, incomplete or incorrect observations. An attempt on the part of the computer to apply any system of theoretical weights, either simple or complex, to such observations is almost certain to lead, at least, to self deception; and the safe as well as reasonable rule in such case would be to use the weight zero.

One example may serve to illustrate the effect of dealing continuously with old observations. In standard star positions the four principal national ephemerides are not only not in accord with each other, but they generally do not exhibit results, even from the few best modern observations. The many discrepancies, of varying magnitude, in these volumes, present with marked emphasis the undesirable results arising from the custom of "threshing old straw."

The data on which these several ephemerides are founded are the common property of all astronomers, and no one can claim the exclusive use of any published observations; and yet national pride or national obstinacy, which is sometimes mistaken for the nobler sentiment, or some computer's pet scheme or system of combination, has led to the adoption of a variety of assumptions in the interpretation and treatment of the original data, until our standard ephemerides are so complex in their structure that the exact details of their preparation are practically unknown outside their respective computing offices. The accuracy of the star positions is unchecked by any recent fundamental observations, and they lack that trustworthy character that should inhere in a system intended to serve as a basis for even good differential work.

If this character were wholly satisfactory, we should soon see the representatives of Astronomy, Geodesy and Geology gathering about the zenith telescope, confident of reaching, by the systematic use of this simple instrument, some definite conclusion in regard to the variation of terrestrial latitudes. But the accurate star positions do not exist, and under the present conditions the most feasible plan for utilizing this instrument is to arrange the observing stations so as to eliminate the effect of errors in the star places.

If it be admitted that sidereal astronomy is worthy of further and more accurate study, that the needs of astronomical research at the present time and in the immediate future demand more exact positions of the standard stars, it may be desirable to consider briefly the status of those agencies to which we must look for the successful prosecution of such an investigation.

It is not an easy task to determine the exact number of active observatories, in the world. Some published lists contain the names of all observatories, from the most expensive and fully equipped government establishments, to the temporary shelter that protects a small equatorial telescope, and perhaps a chronometer, which is kept by the owner for the amusement and possibly for the instruction of himself and his friends. A fair enumeration however would probably give a list of about two hundred and fifty observatories sufficiently equipped to do some kind of astronomical work. Of this number more than twenty per cent are found in North America. In the equipment of these two hundred and fifty observatories are to be found about sixty Transit Circles with objectives ranging from nine to about three inches. The quality of about one-fourth of these instruments is such that good results may be expected from their proper employment. To the latter class of instruments we are limited when we seek for the highest class of work now under consideration. If we take account of the modern subsidiary apparatus and of the electric methods of recording transit observations and illuminating the different parts of the instrument, it does not seem extravagant to conclude that, if one-third of the best Transit Circles were devoted for the next four years to observations for the formation of a fundamental star catalogue of right ascensions and north-polar distances, the aggregate result would be not only the best positions ever published, but it would be of the greatest value in the discussion of current, as well as future, astronomical problems. Unfortunately, however, we do not find any such number of instruments employed in fundamental work. At the present time there is no general fundamental work in progress in any portion of the world, and within the last thirty years there have been no results of that character to take the place of the Pulkowa determinations. This statement does not refer to observations of one ordinate only, or to those cases where several observers, both trained and untrained, are accustomed to observe in turn with the same instrument, and their several results are indiscriminately mingled in such a way that critical discussion is out of the question. Several observers may work together in the determination of declinations with a fair degree of success, because, to a large extent, each observer's work in a period of twelve or twenty-four hours is independent of that of his fellows; but even this work is better when done by one skilled observer alone. Fundamental right ascensions however cannot be determined with the requisite accuracy, and the necessary freedom from systematic errors, if more than one or, at most, two observers work with the same instrument. If only accidental errors of observation, or such as are due to atmospheric disturbances, uncomfortable positions or the unsteady nerves of the observer, were introduced by increasing the number of observers, then increasing the number of observations would tend to diminish the error of the result. But the personal errors of observers and their various habits of manipulation are of the same nature as systematic errors and cannot be eliminated by increasing the list of observers or the number of observations.

Of the many valuable star catalogues in existence I know of none in which the right ascensions depend upon the observations of more than one astronomer, where it is possible to know, or to eliminate, either the constant or the variable errors due to the personal equation of the observers.

In the current astronomical work of this country in which we, as members of this Section, are especially interested, observations and discussions, planned solely, and properly carried out, for the determination of absolute star places, are quite unknown. The necessary instrumental outfit, with the exception in some cases of a clock of the requisite quality, exists in several observatories, and I have no doubt that trained observers of the highest character can be found to meet all demands.

With the exception of a few government establishments and of those built to promote a higher grade of instruction, the observatories throughout the world have been founded generally for some special purpose. Their existence depended upon some endowment or bequest originating in the real or fancied interest which the wealthy benefactor took in some popular branch of the science, and this founder, with a real enthusiasm for the stimulation of research and a noble generosity that deserved recognition in a broader field, often unwittingly limited the scope of his foundation and restrained the usefulness of his gift. Utility or novelty, separately or in combination, were frequently the groundwork on which were based the successful claims for pecuniary assistance in founding and maintaining astronomical observatories. The working observatories founded fifty years or more ago, with scarcely an exception, were supported entirely in the belief that the results of the observations would be, directly or indirectly, beneficial to navigation and to commerce. At that time this belief rested upon a reasonable basis. This plea for the construction and support of observatories is sometimes heard, even at this period in the evolution of science, in spite of the fact that, if every fixed observatory in the world were destroyed to-day, no interest of navigation or commerce would suffer for the next fifty years. The function of astronomy in promoting the development of navigation and in fostering the extension of commerce has been completed.

In the periodical struggle with wealthy patrons to secure the yearly stipend, and with corporations and legislative bodies to obtain the annual appropriations for the support of observatories, may be found perhaps an apparent, if not a sufficient, motive for selecting the class of work that is pursued in most of the American observatories at this time. The apparent conclusion of those who have sought financial support for astronomical observatories seems to have been that such aid could not be secured except for some special work or research, and that the particular branch of investigation selected must be one that promised either immediate and novel results, or such as would enable capital to win, either in material benefits or in popular reputation, some returns for the risks incurred in speculative advances. Persistence in these theories and in the consequent lines of action, has doubtless resulted in the evolution of a certain type of astronomer, and also of a corresponding type of astronomical patron, whether the latter be an individual, a corporation or the legislative agents of millions of intelligent people. Such a result would be the obvious outcome of the forces in action.

The motives that actuate the early settlers in new countries, that guide them in the struggle with the untamed forces of nature, arise mainly from the material interests of the pioneer. As the subjugation of the land progresses and the comforts and the luxuries of life are substituted for the bare necessities of existence, the higher, intellectual side of humanity asserts itself and demands, not only a hearing in the councils, but also its share in the advantages won in the campaign for material prosperity.

The progress in the development of the various stages of civilization has its parallel in the evolution of the science of modern astronomy. For many centuries the timid navigator skirted the familiar shores of his native land, or, occasionally lured by the hope of unusual gains, he rashly tempted fate by adventurous cruises along distant shores that bore no name in the traditions of his forefathers. But, however lofty his ambition, he never allowed the known or unknown peaks and headlands to sink below his horizon. To him, the open ocean was a symbol of infinite space that he dared not explore until astronomy furnished the key to its uttermost recesses, and the art of navigation rose to the dignity of a science.

Greenwich observatory was founded in 1675 to promote the interests of navigation. The royal warrant appointing the first astronomer-royal also declares that his duty is "forthwith to apply himself with the most exact care and diligence to the rectifying the tables of the motions of the heavens and the places of the fixed stars, so as to find out the so much desired longitude of places for the perfecting of the art of navigation." Right faithfully have the successive astronomers-royal carried out the spirit of the regal mandate. For many years the success was far from uniform, nor was the progress always satisfactory, but, through adversity as well as prosperity the original design of the foundation was always kept in view and the results have been commensurate with the effort. If the work of all the other observatories of the world were neglected or destroyed the data in the annual volumes of the Greenwich Observatory would be sufficient, not only to build anew the science of navigation but to reconstruct the entire planetary and lunar theories. Surely there can be no more flattering commentary on the value of a well-planned system of observatory work closely followed, through two centuries, with true Anglo-Saxon pertinacity.

The history of Greenwich Observatory is, in many respects, that of nearly all the observatories of that early epoch which have survived to the present time, but most of the urgent needs that led to their foundation have ceased to exist, and new problems have arisen to take their place. The immediate material and commercial advantages, sought for in obedience to the demands of the original foundations, have been fully gained, and the scientific results obtained from those early researches remain a permanent benefaction to the whole world.

To this extent the science of astronomy is deprived of some, perhaps the most efficient, of the influences that commended it to public approval and support during the last two centuries; and the science has now reached a period in its development where we may with propriety consider two pertinent questions.

First,—what has astronomy gained for itself in the effort to present, in its results, commercial advantages or popular reputation to its patrons, in return for financial support?

Second,—what shall be its future attitude when seeking aid in the foundation and endowment of new observatories or in the maintenance of those already in existence?

It may be assumed without fear of contradiction, that, after the revival of astronomical studies in Europe, the rapid development of practical and applied astronomy and the consequent establishment of a large number of observatories was due to the stimulus derived from newly awakened interests of navigation and commerce. Around these centres of scientific activity the astronomers of the world gathered to discuss not only the problems of practical astronomy but the more abstruse, theoretical questions which lay at the foundation of the higher branches of the science. The work of each observatory not only furnished the means for determining the accuracy of the numerous theories then extant, but it produced original data on which new theories were constructed to be in their turn subjected to the rigid test of observation. In the extreme interest evolved in such discussions, by those who eagerly sought the key to nature's methods in the simple form of general laws, the minor problems of practical astronomy were soon solved, or passed over, to clear the way for the more profound questions that involved the motions in the solar system and the structure of the stellar universe. So, indirectly, at first, with a zeal superior to all obstacles and an ambition that looked beyond the simple and practical ideas underlying the original foundation, astronomers have steadily but persistently sought for nature's general laws in the labyrinth of complex phenomena, have devoted years of intense labor to the most refined tests of methods and theories, and finally, have won for their exacting but fascinating study, the foremost place among the sciences. Success in all these labors has justified the wisdom of those royal and wealthy patrons who generously gave their support when a favorable issue was by no means certain.

In its practical results astronomy has returned to mankind a thousand fold the cost of founding and maintaining its observatories and, at the same time, it has developed a science whose field of action includes, not only the figure, motions and positions of our own insignificant planet, but it reaches the uttermost limits of the universe.

If the second question be regarded as involving only a simple problem in ethics it could be readily answered by following the homely, but sometimes pertinent, injunction to "speak the truth." But in view of the complexity of interests now existing, this question has a wider signification and deserves some consideration. As already stated, utility or commercial advantage can no longer be given as a reason for carrying on astronomical investigations. Novelty, combined with a desire for architectural display and an absurd ambition to secure the largest telescope and the greatest variety of astronomical instruments has even at the present time, a place, and sometimes a prominent one, among the reasons assigned for establishing new observatories. In view of these facts, it is surely the duty of astronomers to see to it that, for their own reputation and for the present and the ultimate welfare of their science, the true purpose of astronomical study and research and the grounds for the existence and the support of observatories should be frankly given and courageously maintained. It is possible that pecuniary profit may sometimes indirectly arise from some branches of astronomical work or investigation; but the only sound and honest reason that can be given for such work is that it stimulates the highest form of intellectual activity, widens the already broad field of investigation and increases the sum of human knowledge. Whoever pleads the cause of astronomy on a lower plane discounts the intelligence of himself or of his audience. Why should the astronomer stoop to select a less noble theme, or consider it from a lower point of view? He who leads an intelligent and thoughtful life must feel himself in daily touch with those phenomena that are involved in the most important astronomical problems of the present time and of the immediate future. The figure and motions of the earth which he treads; the constitution and translation of the sun that invigorates his life and lights his days; the movements and structure of the moon and planets that beautify his nights; the proper motions and distances of the countless stars that nightly set before his eyes the highest types of rigorous law and of boundless space that the mind can grasp;—all of these, and more, tend to convince him that the constantly growing demand for broader and more exact knowledge is ample warrant for the time and expense involved in the most profound astronomical investigation. In this direction lies the justification of astronomical research; on this basis the astronomer is sure of the stimulating support of every cultivated mind as long as the questions "why?" and "how?" are constantly reiterated and are still unanswered; on this ground, and on this alone, rest the valid reasons for the expenditure of corporate, municipal or national funds for the establishment of expensive observatories and the prosecution of astronomical investigations; and in the closing years of this century the conscientious astronomer can in no way more thoroughly vindicate the highest claims of his science than by holding the standard of work well above the popular fancies of the hour, and by devoting his time and energy to that class of fundamental work that shall not only satisfy the rigorous demands of the present time, but shall make the last decade of the nineteenth century an important epoch in the real progress of astronomy.

# PAPERS READ.

ON THE IMAGINARY OF ALGEBRA. By Prof. A. MACFARLANE, University of Texas, Austin, Texas.

The student, if he should hereafter inquire into the assertions of different writers, who contend for what each of them considers as *the* explanation of $\sqrt{-1}$, will do well to substitute the indefinite article."— DE MORGAN, *Double Algebra*, p. 94.

WITH respect to the theory and use of $\sqrt{-1}$ analysts may be divided into three classes: *first*, those who have considered it as *undefined* and *uninterpreted*, and consequently make use of it only in a tentative manner; *second*, those who have considered it as *undefinable* and *uninterpretable*, and build upon this supposed fact a special theory of reasoning; *third*, those who, viewing it as capable of definition, have sought for the definition in the ideas of geometry.

Of the first class we have an example in the view laid down by the astronomer Airy (*Cambridge Philosophical Transactions*, vol. x, p. 827). "I have not the smallest confidence in any result which is essentially obtained by the use of imaginary symbols. I am very glad to use them as conveniently indicating a conclusion which it may afterwards be possible to obtain by strictly logical methods; but until these logical methods shall have been discovered, I regard the result as requiring further demonstration." This view admits that conclusions are indicated by methods which are not strictly logical; that a method which is not strictly logical can indicate and always can indicate a conclusion is a paradox which it is very desirable to explain.

Of the second class we have an example in the mathematician and logician, Boole. Instead of conforming analysis to ordinary reasoning, he endeavors to conform reasoning to analysis by introducing a transcendental species of logic. In his *Laws of Thought*, p. 68, he lays down the following as an axiomatic principle in reasoning: The process of solution or demonstration may be conducted throughout in obedience to certain formal laws of combination of the symbols, without regard to the question of the interpretability of the intermediate results, provided the final result be interpretable. Our knowledge of the foregoing principle is based upon the actual occurrence of an instance, that instance being the imaginary of algebra. In support of this view he says: "A single example of reasoning in which symbols are employed in obedience to laws founded upon their interpretation, but without any sustained reference to that interpretation, the chain of demonstration conducting us through intermediate steps which are not interpretable to a final result which is interpretable, seems not only to establish the validity of the particular application, but to make known to us the general law manifested therein. No accumulation of instances can properly add weight to such evidence. The employment of the uninterpretable symbol $\sqrt{-1}$, in the intermediate processes of trigonometry, furnishes an illustration of what has been said. I apprehend that there is no mode of explaining that application which does not covertly assume the very principle in question. But that principle, though not, as I conceive, warranted by formal reasoning based upon other grounds, seems to deserve a place among those axiomatic truths, which constitute, in some sense, the foundation of the possibility of general knowledge, and which may properly be regarded as expressions of the mind's own laws and constitution."

Inasmuch as the successful use of the undefined symbol $\sqrt{-1}$ by analysts is thus made the basis of a sort of transcendental logic, it is a matter of interest to investigate whether the intermediate steps in such demonstrations are not uninterpretable but merely uninterpreted. If it can be shown that some at least of the expressions in which $\sqrt{-1}$ occurs have a real geometrical meaning, the argument for a transcendental logic will fail.

The "principle of the permanence of equivalent forms," which was by Peacock made the foundation of the operations and results of algebra, is scarcely so transcendental, but is certainly a very vague and unsound principle of generalization. He states it as follows (*Symbolical Algebra*, p. 631): "*Whatever algebraical forms are equivalent, when the symbols are general in form but specific in value, will be equivalent likewise when the symbols are general in value as well as in form.* It will follow from this principle that all the results of arithmetical algebra will be results likewise of symbolical algebra, and the discovery of equivalent forms in the former science possessing the requisite conditions will be not only their discovery in the latter, but *the only* authority for their existence; for there are no definitions of the operations in symbolical algebra by which such equivalent forms can be detected."

The principle is applied to indices in the following manner: "Observing that the indices $m$ and $n$ in the expressions which constitute the equation $a^m \times a^n = a^{m+n}$, though *specific* in value, are *general* in form we are authorized to conclude by the principle of the permanence of equivalent forms that in symbolical algebra the same expressions continue to be equivalent to each other for *all values* of those indices; or, in other words, that $a^m \times a^n = a^{m+n}$ whatever be the values of $m$ and $n$."

The question is: How general may the symbols be made, yet the equation still retain the same form? This is not a question of nominal definition and merely symbolical truth, but of real definition and of real truth; as may be shown by considering the above principle of indices. For a certain generalized meaning of $m$ and $n$, Hamilton (Elements of Quaternions, p. 388) investigates whether or not $a^m \times a^n = a^{m+n}$, and concludes that it is not true. With him the question is one of material truth, not of symbolical definition.

The above principle of generalization may be tested in another way. If $r$ denote the ordinary algebraic quantity which may be positive or negative, $r \cdot \theta$ may represent that quantity when generalized so as to have any angle $\theta$ with an initial line in a given plane. For this generalized magnitude

$$r \cdot \theta \times r' \cdot \theta' = rr' \cdot \theta + \theta';$$

in words, the length of the product is the product of the lengths, and the angle of the product is the sum of the angles. Now the principle of the permanence of equivalent forms does not help us to generalize this proposition for space. A plausible hypothesis likely to present itself at first is: Let $\varphi$ denote the angle between the given plane and a fixed plane, is

$$(r \cdot \theta \cdot \varphi) \times (r' \cdot \theta' \cdot \varphi') = rr' \cdot \theta + \theta' \cdot \varphi + \varphi'?$$

This is a question not of symbolism, but of truth.

At the time of De Morgan there was no adequate theory of $\sqrt{-1}$, as is evident from the quotation prefixed; nor is there at the present time. The view at present held about $i = \sqrt{-1}$ by analysts is thus stated by Cayley in a paper "On Multiple Algebra," printed in the *Quarterly Journal of Mathematics*, vol. XXII.

"We have come to regard $a + bi$ as an ordinary analytical magnitude, viz.: in every case an ordinary symbol represents or may represent such a magnitude, and the magnitude (and as a particular case thereof the symbol $i$) is commutable with the extraordinaries of any system of multiple algebra; and similarly in analytical geometry without seeking for any real representation we deal with imaginary points, lines, etc., that is, with points, lines, etc., depending on parameters of the form $a + bi$."

I propose to review critically the different explanations or elements of explanation which have been contributed, with the hope of finding a theory which will tend to unify them, and to diminish still further that region of analysis where we have mere symbolism without real definition.

The investigation of this subject arose with the celebrated controversy about the nature of the logarithms of negative numbers; whether they are real or impossible. Leibnitz maintained that the logarithm of a negative number is impossible, because if log (—2) is real, so is $\frac{1}{2}$ log (—2), that is log $\sqrt{-2}$, which would lead to the supposed absurdity of the logarithm of an impossible quantity being real. John Bernoulli held that the logarithm of a negative number is as real as the logarithm of a positive number; for the ratio $-m : -n$ does not differ from that of $+m : +n$. The former view was afterwards maintained by Euler, the latter by D'Alembert. Euler claimed to demonstrate that every positive number has an infinite number of logarithms, of which only one is possible; further, that every negative as well as every impossible number has an infinite number of logarithms, which are all impossible. He reasoned from the values of the $n^{th}$ root of $+1$ and of $-1$, viewing $+$ as denoting an even number, and $-$ as denoting an odd number, of half revolutions. D'Alembert pointed out that the logarithm of a negative number may be real. Thus $e^{\frac{1}{2}} = +\sqrt{e}$ or $-\sqrt{e}$; but the logarithm of $e^{\frac{1}{2}}$ is $\frac{1}{2}$; therefore the logarithm of $-\sqrt{e}$ as well as of $+\sqrt{e}$ is $\frac{1}{2}$.

These opposing views arise from different conceptions of the negative symbol and of the magnitude treated by algebra. The magnitudes considered in elementary algebra are, first, a mere number or ratio; second, a magnitude which may have a given direction, or the opposite, and third, a geometric ratio which combines a number with a certain amount of change of direction. The logarithm of a ratio is itself a ratio, and is unique. If a directed magnitude has a logarithm, it is difficult to see how the direction of the logarithm, if it has any direction, can be different from that of the magnitude. It is of number in the sense of a geometric ratio that Euler's proposition is true. This conception of number immediately transcends representation by a single straight line; consequently a part of the ratio generally appears as impossible.

In his *Geometrie de Position*, Carnot asks the following among other questions: "If two quantities, of which the one is positive and the other negative, are both real, and do not differ excepting in position, why should the root of the one be an imaginary quantity, while that of the other is real? Why should $\sqrt{-a}$ not be as real as $\sqrt{+a}$?" In this question it is assumed that $-a$ and $+a$ denote directed magnitudes, the one being opposite to the other; and if such a quantity has a square root, it is difficult to understand why the one direction should differ from the other. But the $-a$ which has the imaginary square roots, while $+a$ has real, do not differ in direction; they differ in the amount of change of direction.

In 1806, M. Bueé published in the *Philosophical Transactions* a memoir on Imaginary Quantities, and in it he endeavors to answer some of the questions raised by Carnot. His main idea is that $+$, $-$, and $\sqrt{-1}$ are purely descriptive signs; that is, signs which indicate direction. Suppose three equal lines $AB$, $AC$, $AD$, drawn from a point $A$ (fig. 1), of which $AC$ is opposite to $AB$, and $AD$ perpendicular to $BAC$; then if the line $AB$ is designated by $+1$, the line $AC$ will be $-1$, and the line $AD$ will be $\sqrt{-1}$. Thus $\sqrt{-1}$ is the sign of perpendicularity. It follows from this view of $\sqrt{-1}$ that it does not indicate a unique direction, the opposite line $AD'$, or any line in the plane as $AD''$ is also indicated by $\sqrt{-1}$. Bueé admits the consequence. But it may be asked: If every perpendicular is represented by $\sqrt{-1}$, what meaning is left for $-\sqrt{-1}$?

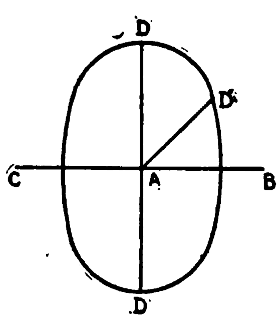

FIG. 1.

Bueé applies his theory to the interpretation of the solution of a quadratic equation which had been considered by Carnot, namely: To divide a line $AB$ into two parts such that the product of the segments shall be equal to half the square of the line.

Let $AB$ (fig. 2) be the given line, and suppose $K$ to be the required point; let $AB$ be denoted by $a$, and $AK$ by $x$; then by the given condition

$$x\,(a-x)=\frac{a^2}{2}$$

and by the ordinary process of solution

$$x=\frac{a}{2}\pm\sqrt{-\frac{a^2}{4}}=\frac{a}{2}\pm\sqrt{-1}\,\frac{a}{2}.$$

According to Carnot, the appearance of the imaginary indicates that there is no such point as is required between $A$ and $B$, but that it is outside $AB$

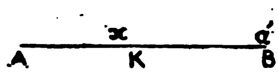


FIG. 2.

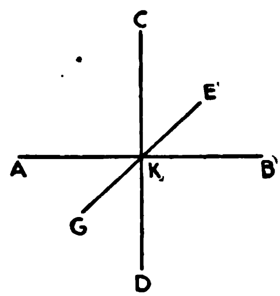


FIG. 3.

on the line prolonged. If it is supposed to be beyond $B$ on the line produced, the equation takes the modified form $x\,(x-a)=\frac{1}{2}\,a^2$, giving

$$x=\tfrac{1}{2}a\pm\sqrt{\frac{3a^2}{4}}$$

Of these two roots he considers

$$x=\tfrac{1}{2}\,a+\sqrt{\frac{3a^2}{4}}$$

only to be a true solution of the question; while

$$x=\frac{a}{2}-\sqrt{\frac{3a^2}{4}}$$

is the solution on the hypothesis that the point is on the line produced, but on the side of $A$. Bueé views these answers as the solutions of connected equations, not of the given equation. His solution is represented (fig. 3) by drawing two mutual perpendiculars $KC$ and $KE$ to represent $\sqrt{-1}\,\frac{a}{2}$ and their opposites $KD$ and $KG$ to represent $-\sqrt{-1}\,\frac{a}{2}$; $C$ and $D$ or $E$ and $G$ are the points required. But Bueé does not show how the square of $\frac{a}{2}+\sqrt{-1}\,\frac{a}{2}$ is to be represented? If the one component of the line is perpendicular to the other, ought not the square of the sum to be equal to the sum of the squares? But this does not agree with the principles of algebra, for

$$(x+\sqrt{-1}\,y)^2=x^2-y^2+2\sqrt{-1}\,xy.$$

This is a difficulty which a theory of mere direction cannot get over. Led by his theory of perpendicularity, Bueé considers the question: What does a conic section become, when its ordinates become imaginary? Consider a circle; when $x$ has any value between $-a$ and $+a$, then

$$y = \pm\sqrt{a^2 - x^2}$$

But when $x$ is greater than $a$, or less than $-a$, let it be denoted by $x'$, and the analogue of $y$ by $y'$, then

$$y' = \pm\sqrt{-1}\,\sqrt{x'^2 - a^2}.$$

Bueé advances the view that the circle in the plane of the paper changes into an equilateral hyperbola in the plane perpendicular to the plane of the paper; but he does not prove the suggestion, or test it by application to calculation. A similar view has been developed by Phillips and Beebe in their "Graphic Algebra." It appears to me that here we have a fundamental question in the theory of $\sqrt{-1}$. The expression $\sqrt{a^2-x^2}$ denotes the ordinate of the circle, what is represented by $\sqrt{-1}\,\sqrt{x'^2-a^2}$, $x'$ being greater than $a$?

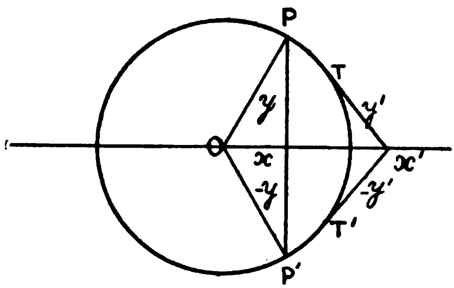


FIG. 4.

The former is constructed by drawing from the extremity of $x$ a straight line at right angles to it in the given plane, and describing with centre $O$ a circle of radius $a$ the point of intersection $P$ determining the length of the ordinate, and $-\sqrt{a^2-x^2}$ is equal and opposite. Now (fig. 4) $\sqrt{x'^2-a^2}$ is equal in length to the tangent from the extremity of $x'$ to the circle, and $\sqrt{-1}$ appears to indicate the direction of the tangent, which varies in inclination to the axis of $x$, but is determined by always being perpendicular to the radius at the point of contact. Hence if $x'$ be considered a directed magnitude, the expression

$$x' + \sqrt{-1}\,\sqrt{x'^2-a^2}$$

denotes the radius from $O$ to the one point of contact $T$, while

$$x' - \sqrt{-1}\,\sqrt{x^2-a^2}$$

denotes the radius to the other point of contact $T'$. This construction does not necessitate going out of the given plane; and if space be considered we have a whole complex of ordinates to the sphere, as well as a complex of tangents to the sphere. The ordinary theory of minus gives no explanation of the double sign in the case of the tangent. It is true in the case of the two ordinates, that the one is opposite to the other in direction, but it is not true of the two tangents. In the case of the sphere the ordinate may have any direction in a plane perpendicular to $x$, while the tangent may have any direction in a cone of which $x$ is the axis. This other and hitherto unnoticed meaning of $\sqrt{-1}$ will be developed more fully in the investigation which follows (p. 52).

The same year, Argand published his "*Essai sur une manière de représenter les quantités imaginaires dans les constructions géométriques.*" His method is restricted to a plane (fig. 5). According to his view $+$ is a sign of direction, $-$ of the opposite direction, $\sqrt{-1}$ of the upward perpendicular direction and $-\sqrt{-1}$ of the downward perpendicular direction. The general quantity $a + b\sqrt{-1}$ is represented by a line $OP$ (fig. 5) having $a$ and $b\sqrt{-1}$ for rectangular components. The product of two lines $a + b\sqrt{-1}$ and $a' + b'\sqrt{-1}$ is

$$(a + b\sqrt{-1})(a' + b'\sqrt{-1}) = aa' - bb' + \sqrt{-1}(ab' + a'b)$$

and it too is represented by a line, namely, the line which has $aa' - bb'$ and $\sqrt{-1}(ab' + ba')$ for rectangular components.

A very important advance was made by Français, who perceived that $+$, $-$, $\sqrt{-1}$ and $-\sqrt{-1}$ did not denote directions, but rather amounts of angle. He introduced the notation $a_\alpha$ to denote the general line where $a$ denotes its magnitude and $\alpha$ the angle between it and a fixed initial line. Thus $+a$ is $a_0$, $-a$ is $a_\pi$, $\sqrt{-1}a$ is $a_{\frac{\pi}{2}}$, and $-\sqrt{-1}a$ is $a_{-\frac{\pi}{2}}$. So long as $\alpha$ is supposed to denote the angle specifying the position of a line, it is difficult to perceive what is the meaning of the multiplication or division of two lines. It was customary to look upon the product line as forming a fourth proportional to the initial line and the two given lines. But when it is perceived[1] that the angle does not refer to a fixed initial line, but to any line in the plane, it becomes evident that the product of two quantities $r_\theta$ and $r'_{\theta'}$ is $rr'_{\theta+\theta'}$, the ratio of the product being the product of the ratios, and the angle of the product being the sum, or what appears to be the sum, of the angles. In the investigation of Français, the symbol $\sqrt{-1}$, though replaced by $\frac{\pi}{2}$ in the primary quantity, reappears again in the exponential expression for a line; he writes

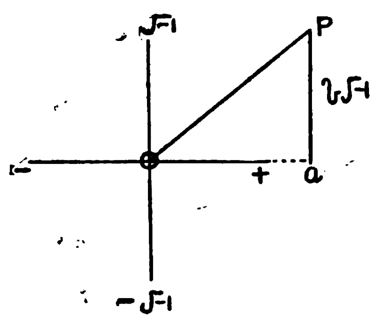


FIG. 5.

$$ae^{\alpha\sqrt{-1}} = a_\alpha.$$

He does not appear to have considered the question: Can the $\sqrt{-1}$ in this index be replaced by $\frac{\pi}{2}$? It is evident that $\frac{\pi}{2}$ cannot be substituted for it as a simple multiplier; does the index really mean $a_{\frac{\pi}{2}}$, a quantity similar to $a_\alpha$? This question is, I believe, correctly answered by an affirmative. The view which has been commonly taken by analysts is that everything is explained provided $a + b\sqrt{-1}$ is explained, and provided every

[1] *Note on Plane Algebra*, by the author. Proc. R. S. E., 1883, p. 184.

other function involving $\sqrt{-1}$ can be reduced to the form $P + Q\sqrt{-1}$. But it cannot be proved that this reduction is always possible, unless on the assumption that all the imaginaries refer to one plane. For example, De Morgan, in his *Double Algebra*, does not interpret directly $e^{a\sqrt{-1}}$ or the more general expression $(a + b\sqrt{-1})^{p+q\sqrt{-1}}$, but the expression is *reduced to significance* by being reduced to the form $P + Q\sqrt{-1}$. And this is the current mode in modern analysis of explaining functions of the imaginary.

In a subsequent paper Argand adopted the notation of Français for a line in a plane; but used $\frac{1}{4}$ instead of $\frac{\pi}{2}$ to denote the quadrant, which, as Français pointed out, is not an improvement. So imbued was he with the *direction* theory of $\sqrt{-1}$ that he sought to express any direction in space by means of an imaginary function. He arrived at the view that the third mutual perpendicular $KP$ (fig. 6) is expressed by $\sqrt{-1}^{\sqrt{-1}}$, the opposite line $KQ$ by $-\sqrt{-1}^{\sqrt{-1}}$, and any line $KM$ in the perpendicular plane by $\sqrt{-1}^{\cos\mu + \sqrt{-1}\sin\mu}$ where $\mu$ denotes the angle between $KB$ and $KM$.

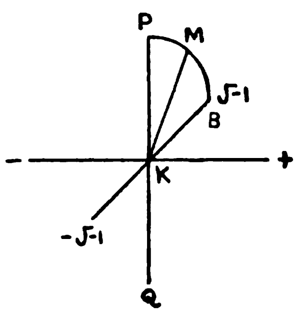

FIG. 6.

He remarks that if the above be the correct meaning of $\sqrt{-1}^{\sqrt{-1}}$, then it is not true that every function can be reduced to the form $p + q\sqrt{-1}$ and he doubts the validity of the current demonstration which aims at proving that the function $(a + b\sqrt{-1})^{m+n\sqrt{-1}}$ can always be reduced to the form $p + q\sqrt{-1}$. According to that reduction, as was shown by Euler, $\sqrt{-1}^{\sqrt{-1}} = e^{-\frac{\pi}{2}}$, and this meaning of the expression was maintained by Français and Servois. The latter, following the analogy of $a + b\sqrt{-1}$ for a line in one plane, suggested that the expression for a line in space had the form

$$p\cos\alpha + q\cos\beta + r\cos\gamma,$$

where $p$, $q$, $r$ are imaginaries of some sort, but he questioned whether they are each reducible to the form $A + B\sqrt{-1}$. In reply to the criticisms of Français and Servois, Argand maintained that Euler had not demonstrated that

$$e^{x\sqrt{-1}} = \cos x + \sqrt{-1}\sin x$$

but had defined the meaning of $e^{x\sqrt{-1}}$ by extending the theorem

$$e^x = 1 + x + \frac{x^2}{2!} + \text{etc.}$$

It will be shown afterwards that in the equation of Euler, namely

$$\sqrt{-1}^{\sqrt{-1}} = e^{-\frac{\pi}{2}}$$

there is an assumption that the axes of the two angles are coincident; and that Argand's meaning is incorrect.

The ideas of Warren in his *Treatise on the geometrical representation of the square roots of negative quantities*, 1828, are essentially the same as those of Français, but they receive a more complete development.

It is curious to find, considering the intensely geometrical character of quaternions, that Hamilton was led by the Kantian ideas of space and time to start out with the theory that algebra is the science of time, as geometry is the science of space, and that he strove hard to find on that basis a meaning for the square root of minus one. But having observed the success, so far as the plane is concerned, of the geometrical theory of Argand, Français and Warren, he adopted a geometrical basis and took up the problem of extending their method to space. What he sought for was the product of two directed lines in space, in the sense of a fourth proportional to two given lines and an initial line. He perceived that one root of the difficulty which had been experienced lay in regarding the initial line as real, and the two perpendiculars as expressed by imaginaries; and, looking at the symmetry of space, adopted the view that each of the three axes should be treated as an imaginary. He was thus led to the principle that if $i$, $j$, $k$ denote three mutually rectangular axes, then

$$i^2 = -1, j^2 = -1, k^2 = -1,$$

and if $Ua$ denote any vector of unit length $(Ua)^2 = -1$. Hence follows the paradoxical conclusion that the square of a directed magnitude is negative, which is contrary to the principles of analysis. An after development of Hamilton's was to give to $i$, $j$, $k$ a double meaning, namely: to signify not only unit vectors, but to signify the axes of quadrantal versors. But in the quaternion we have for the first time the clear distinction between a line and a geometric ratio. In a paper read before this Association last year I have given reasons for believing that the identification of a directed line with a quadrantal quaternion is the principal cause of the obscurity in the method, and of its want of perfect harmony with the other methods of analysis.

The imaginary symbol, notwithstanding its apparent banishment from space, reappears in Hamilton's works as the coëfficient of an unreal quaternion. He appears to hold that there is a scalar $\sqrt{-1}$ distinct from that vector $\sqrt{-1}$ which can be replaced by $i$, $j$, $k$. In the recent edition of Tait's *Treatise on Quaternions*, Prof. Cayley contributes an analytical theory of quaternions, in which the components $w$, $x$, $y$, $z$ of a quaternion are considered in the most general case to have the form $a + b\sqrt{-1}$ where $\sqrt{-1}$ is the imaginary of ordinary algebra. Thus it appears as if we were landed in an analytic theory of quaternions instead of a quaternionic theory of analysis.

In a work recently published on quaternions (*Theorie der Quaternionen*, by Dr. Molenbroek), the principal novelty is the introduction of the symbol $\sqrt{-1}$ with the meaning attached to it by Bueé, namely: to denote perpendicularity. Thus (fig. 7) $\sqrt{-1}\ \alpha$ denotes any vector such as $OP$ or $OQ$, which is equal in length to $\alpha$, and perpendicular to $\alpha$, and $\sqrt{-1}$ is thus made to mean a quadrantal versor with an indefinite axis; but the axis is not entirely indefinite, for it must be perpendicular to $\alpha$. Doubtless it is convenient to have a notation for any direction from $O$ which is perpendicular to $\alpha$; but it does not follow that $\sqrt{-1}$ denotes it properly.

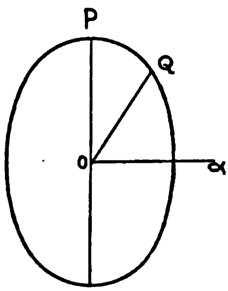

FIG. 7.

I have found the following notation convenient: Let $\alpha$, $\beta$ denote two independent axes, then the axis perpendicular to both may be denoted by $\overline{\alpha\beta}$. In harmony with this notation $\bar{\alpha}$ denotes any of the perpendiculars to $\alpha$; but $\bar{\alpha}$ may also be used to denote a definite perpendicular, when the conditions make the perpendicular definite.

In a paper read before this Association last year[1] I showed that the products of directed magnitudes may be considered in complete independence of the idea of rotation; consequently that the method of dealing with such quantities forms a special branch of the algebra of space, of great importance to the physicist. The method of dealing with versors forms another distinct branch; and in the idea of a versor, or more generally of a geometric ratio or quaternion we find a true explanation of $\sqrt{-1}$, and I believe that the following development will show that it has at least one other geometric meaning.

## SPHERICAL TRIGONOMETRY.

*Notation for a quaternion.*

A quaternion, or geometric ratio, will be denoted synthetically by **a**, and analytically by $a\alpha^{A}$ where $a$ denotes the arithmetical ratio, $\alpha$ the axis, and $A$ the angle in circular measure. The factor $\alpha^{A}$ forms the versor or circular sector. Let $A$ become $\frac{\pi}{2}$, then $\alpha^{\frac{\pi}{2}}$ is an imaginary made definite; $\beta^{\frac{\pi}{2}}$ is another differing from the former as regards its axis.

According to the notation of Hamilton, $\alpha^{1}$ denotes a quadrantal versor, whereas, according to the above definition, it denotes a circular sector of which the arc is unity the radius also being unity. Viewed merely as a matter of convenience in writing and printing, the notation $\alpha^{A}$ is preferable to $\alpha^{\frac{2A}{\pi}}$. For the sake of the extension to hyperbolic sectors, it is found necessary to consider $A$ as denoting not the circular arc but double the

[1] Proc. A. A. A. S., Vol. XL, p. 65.

area of the sector included by the arc. This notation is capable of generalization, while the other is not.

*Meaning of the equation* $a^A = \cos A + \sin A \cdot a^{\frac{\pi}{2}}$

Let $OP$ (fig. 8) be any line of unit length in the plane of $a$, and let $OQ$ be the line from $O$ to the extremity of the circular sector of area $\frac{A}{2}$ enclosed between $OP$ and the circular arc: then

$$\begin{aligned} OQ &= OM + MQ \\ &= \cos A \cdot OP + \sin A\ a^{\frac{\pi}{2}} \cdot OP \\ &= \left(\cos A + \sin A \cdot a^{\frac{\pi}{2}}\right) OP \\ &= a^A\ OP \end{aligned}$$

therefore $$a^A = \cos A + \sin A \cdot a^{\frac{\pi}{2}}.$$

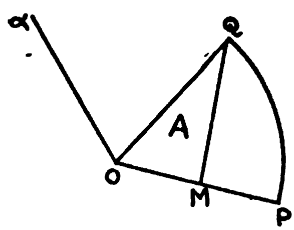


FIG 8.

This equation is true so far as the amount of angle is concerned but not it may be as regards the whole amount of turning. In this sense $\cos A$ and $\sin A \cdot a^{\frac{\pi}{2}}$ are the components of $a^A$.

*To prove that* $a^A = e^{Aa^{\frac{\pi}{2}}}$.

We have $$a^A = \cos A + \sin A \cdot a^{\frac{\pi}{2}},$$

and $$\cos A = 1 - \frac{A^2}{2!} + \frac{A^4}{4!} - ,$$

and $$\sin A = A - \frac{A^3}{3!} + \frac{A^5}{5!} - .$$

By restoring the powers of $a^{\frac{\pi}{2}}$ in the expression for $\cos A$ we obtain

$$\cos A = 1 + \frac{A^2 a^{2\frac{\pi}{2}}}{2!} + \frac{A^4 a^{4\frac{\pi}{2}}}{4!} + ;$$

and by a similar restoration in the series for $Sin\ A$

$$\sin A \cdot a^{\frac{\pi}{2}} = Aa^{\frac{\pi}{2}} + \frac{A^3 a^{3\frac{\pi}{2}}}{3!} + ;$$

and by adding the two series together we get

$$a^A = 1 + Aa^{\frac{\pi}{2}} + \frac{A^2 a^{2\frac{\pi}{2}}}{2!} + \frac{A^3 a^{3\frac{\pi}{2}}}{3!} + ;$$

$$= e^{Aa^{\frac{\pi}{2}}}$$

Also $$(-a)^A = a^{-A} = e^{Aa^{-\frac{\pi}{2}}} = e^{-A \cdot a^{\frac{\pi}{2}}}$$

and $$a^{2\pi - A} = e^{Aa^{3\frac{\pi}{2}}}.$$

So far as angle is concerned, irrespective of the whole amount of turning, we have

$$a^{-A} = a^{2\pi - A}.$$

It follows that $Aa^{\frac{\pi}{2}}$ is the logarithm of $a^A$; and $a^{\frac{\pi}{2}}$ the logarithm of $a^1$.

As the most general expression for minus is $a^{(2n+1)\pi}$,

$$log\ (-1) = (2n+1)\pi \cdot a^{\frac{\pi}{2}}.$$

The general expression for $\sqrt{-1}$ is $a^{\frac{\pi}{2}+2n\pi}$, therefore

$log \sqrt{-1} = (2n\pi + \frac{\pi}{2}) \cdot a^{\frac{\pi}{2}}$; and for $+$ it is $a^{2n\pi}$, therefore $log + = 2n\pi \cdot a^{\frac{\pi}{2}}$.

Hence generally $\quad log\ (aa^A) = log\ a + A \cdot a^{\frac{\pi}{2}}$.

In his *Geometrie de Position* Carnot says, in reference to the celebrated discussion about the logarithms of negative quantities "Quoique cette discussion soit aujourd'hui terminé, il reste ce paradoxe savoir que quoiqu' on ait $log\ (-x)^2 = log\ (x)^2$, on n'a cependant pas $2\ log\ (-x) = 2\ log\ x$."

The paradox may be explained as follows: Suppose the complete expression for $x$ to be $xa^{2n\pi}$, then that for $-x$ is $xa^{(2n+1)\pi}$; then

$$log\ x^2 = 2\ log\ x + 4n\pi \cdot a^{\frac{\pi}{2}} \text{ and } log\ (-x)^2 = 2\ log\ x + (4n+2)\pi \cdot a^{\frac{\pi}{2}}.$$

As the latter is twice the logarithm of $xa^{(2n+1)\pi}$, the supposed paradox vanishes.

*To prove that*

$$a^A \beta^B = cos\ A\ cos\ B - sin\ A\ sin\ B\ cos\ a\beta$$

$$+ cos\ A\ sin\ B \cdot \beta^{\frac{\pi}{2}} + cos\ B\ sin\ A \cdot a^{\frac{\pi}{2}} - sin\ A\ sin\ B\ sin\ a\beta \cdot \overline{a\beta}^{\frac{\pi}{2}}.$$

Since $$a^A = cos\ A + sin\ A \cdot a^{\frac{\pi}{2}},$$

and $$\beta^B = cos\ B + sin\ B \cdot \beta^{\frac{\pi}{2}},$$

by multiplying the two equations together we obtain

$$a^A \beta^B = cos\ A\ cos\ B + cos\ A\ sin\ B \cdot \beta^{\frac{\pi}{2}} + cos\ B\ sin\ A \cdot a^{\frac{\pi}{2}} + sin\ A\ sin\ B \cdot a^{\frac{\pi}{2}} \beta^{\frac{\pi}{2}}.$$

Now, as was shown in the previous paper (p. 98)

$$a^{\frac{\pi}{2}} \beta^{\frac{\pi}{2}} = -cos\ a\beta - sin\ a\beta \cdot \overline{a\beta}^{\frac{\pi}{2}};$$

hence

$$\cos \alpha^A \beta^B = \cos A \cos B - \sin A \sin B \cos \alpha\beta \qquad (1),$$

and

$$Sin\, \alpha^A\beta^B = \left\{\cos A \sin B \cdot \beta + \cos B \sin A \cdot \alpha - \sin A \sin B \sin \alpha\beta \cdot \overline{\alpha\beta}\right\}^{\frac{\pi}{2}} \quad (2).$$

Equation (1) expresses what is held to be the fundamental theorem of spherical trigonometry; but the complementary theorem expressed by (2) is never considered. So far as magnitude is concerned, it may be derived from (1) by the relation $\cos^2 \theta + \sin^2 \theta = 1$; but it is not so as regards the axis. Equation (1) is the generalization of the theorem of plane trigonometry

$$\cos (A + B) = \cos A \cos B - \sin A \sin B;$$

while equation (2) is the true generalization of the complementary theorem

$$\sin (A + B) = \cos A \sin B + \cos B \sin A.$$

The one theorem may perhaps be derived logically from the other, when restricted to the plane, but it is not so in space. The two equations form together what is called the addition theorem in plane trigonometry. Why do we have addition on the one side of the equation, while we have multiplication on the other? Because $A + B$ is the sum of two indices of an axis which is not expressed, the complete expression being

$$\cos \alpha^{A+B} = \cos A \cos B - \sin A \sin B$$

$$Sin\, \alpha^{A+B} = (\cos A \sin B + \cos B \sin A) \cdot \alpha^{\frac{\pi}{2}}.$$

*Prosthaphaeresis in spherical trigonometry.*

The formula for $\alpha^A \beta^{-B}$ is obtained from that for $\alpha^A\beta^B$ by putting a minus before the $\sin B$ factor. Hence

$$\cos \alpha^A \beta^{-B} = \cos A \cos B + \sin A \sin B \cos \alpha\beta, \text{ and}$$

$$Sin\, \alpha^A \beta^{-B} = -\cos A \sin B \cdot \beta^{\frac{\pi}{2}} + \cos B \sin A \cdot \alpha^{\frac{\pi}{2}} + \sin A \sin B \sin \alpha\beta \cdot \overline{\alpha\beta}^{\frac{\pi}{2}}.$$

Hence the generalizations for space of

$$\cos (A-B) + \cos (A+B) = 2 \cos A \cos B,$$
$$\cos (A-B) - \cos (A+B) = 2 \sin A \sin B,$$
$$\sin (A+B) + \sin (A-B) = 2 \cos B \sin A,$$
$$\sin (A+B) - \sin (A-B) = 2 \cos A \sin B,$$

are respectively

$$\cos \alpha^A \beta^{-B} + \cos \alpha^A \beta^B = 2 \cos A \cos B,$$
$$\cos \alpha^A \beta^{-B} - \cos \alpha^A \beta^B = 2 \sin A \sin B \cos \alpha\beta,$$
$$Sin\, \alpha^A \beta^B + Sin\, \alpha^A \beta^{-B} = 2 \cos B \sin A \cdot \alpha^{\frac{\pi}{2}},$$
$$Sin\, \alpha^A \beta^B - Sin\, \alpha^A \beta^{-B} = 2\left\{\cos A \sin B \cdot \beta - \sin A \sin B \sin \alpha\beta \cdot \overline{\alpha\beta}\right\}^{\frac{\pi}{2}}$$

Let

$$\alpha^A \beta^B = \gamma^C \text{ and } \alpha^A \beta^{-B} = \delta^D \text{ (fig. 9)}$$

then $$\beta^B \alpha^{-A} \alpha^A \beta^B = \delta^{-D}\gamma^C = \beta^{2B};$$

therefore $$\frac{\delta^{-D}\gamma^C}{2} = \beta^B$$

Also $$\delta^D \frac{\delta^{-D}\gamma^C}{2} = \alpha \quad ;$$

but this does not reduce to $$\frac{\delta^D\gamma^C}{2} = \alpha^A$$

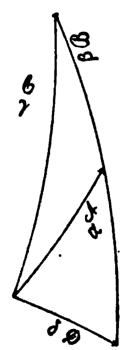

FIG. 9.

Hence

$$\cos\delta^D + \cos\gamma^C = 2\cos\left\{\delta^D \frac{\delta^{-D}\gamma^C}{2}\right\}\cos\frac{\delta^{-D}\gamma^C}{2};$$

$$\cos\delta^D - \cos\gamma^C = 2\sin\left\{\delta^D \frac{\delta^{-D}\gamma^C}{2}\right\}\sin\frac{\delta^{-D}\gamma^C}{2}\cos\alpha\beta;$$

etc.

*To prove that* $\alpha^A\beta^B = e^{A\alpha^{\frac{\pi}{2}} + B\beta^{\frac{\pi}{2}}}$.

Since $$\alpha^A = 1 + A\alpha^{\frac{\pi}{2}} + \frac{A^2\alpha^{2\frac{\pi}{2}}}{2!} + \frac{A^3\alpha^{3\frac{\pi}{2}}}{3!} +,$$

and $$\beta^B = 1 + B\beta^{\frac{\pi}{2}} + \frac{B^2\beta^{2\frac{\pi}{2}}}{2!} + \frac{B^3\beta^{3\frac{\pi}{2}}}{3!} +,$$

$$\begin{aligned}\alpha^A\beta^B = 1 &+ A\alpha^{\frac{\pi}{2}} + \frac{A^2\alpha^{\pi}}{2!} + \frac{A^3\alpha^{3\frac{\pi}{2}}}{3!} + \\ &+ B\beta^{\frac{\pi}{2}} + AB\alpha^{\frac{\pi}{2}}\beta^{\frac{\pi}{2}} + \frac{A^2B}{2!}\alpha^{\pi}\beta^{\frac{\pi}{2}} + \\ &+ \frac{B^2\beta^{\pi}}{2!} + \frac{AB^2}{2!}\alpha^{\frac{\pi}{2}}\beta^{\pi} + \\ &+ \frac{B^3}{3!}\beta^{3\frac{\pi}{2}} +\end{aligned}$$

$$= 1 + (A\alpha^{\frac{\pi}{2}} + B\beta^{\frac{\pi}{2}}) + \frac{(A\alpha^{\frac{\pi}{2}} + B\beta^{\frac{\pi}{2}})^2}{2!} + \ldots + \frac{(A\alpha^{\frac{\pi}{2}} + B\beta^{\frac{\pi}{2}})^n}{n!} +$$
$$= e^{A\alpha^{\frac{\pi}{2}} + B\beta^{\frac{\pi}{2}}}.$$

The general term is

$$\frac{1}{n!}\left\{A^n\alpha^{n\frac{\pi}{2}} + nA^{n-1}\,B\alpha^{(n-1)\frac{\pi}{2}}\,\beta^{\frac{\pi}{2}} + \frac{n(n-1)}{2!}\,A^{n-2}\,B^2\alpha^{(n-2)\frac{\pi}{2}}\,\beta^{\pi} + \right\}$$

which is formed according to the binomial theorem, only the order of $\alpha$, $\beta$ must be preserved in each term.

The binomial here is the sum of two logarithms, not a sum of two quaternions. It is not true that

$$e^{A\alpha^{\frac{\pi}{2}} + B\beta^{\frac{\pi}{2}}} = e^{(A\alpha + B\beta)^{\frac{\pi}{2}}},$$

for
$$e^{(A\alpha + B\beta)^{\frac{\pi}{2}}} = 1 + (A\alpha + B\beta)^{\frac{\pi}{2}} + \frac{\{(A\alpha + B\beta)^2\}^{\pi}}{2!} +$$
$$= 1 - \frac{A^2 + B^2 + 2\,A\,B\cos\alpha\beta}{2!} + \frac{(A^2 + B^2 + 2\,A\,B\cos\alpha\beta)^2}{4!} -$$
$$+ \left\{1 - \frac{A^2 + B^2 + 2\,A\,B\cos\alpha\beta}{3!} + \right\}(A\alpha + B\beta)^{\frac{\pi}{2}}$$

In a similar manner it may be shown that

$$\alpha^A\beta^B\gamma^C = 1 + A\alpha^{\frac{\pi}{2}} + B\beta^{\frac{\pi}{2}} + C\gamma^{\frac{\pi}{2}}$$
$$+ \frac{1}{2!}\left\{A^2\alpha^{\pi} + B^2\beta^{\pi} + C^2\gamma^{\pi} + 2AB\alpha^{\frac{\pi}{2}}\beta^{\frac{\pi}{2}} + 2AC\alpha^{\frac{\pi}{2}}\gamma^{\frac{\pi}{2}} + 2BC\beta^{\frac{\pi}{2}}\gamma^{\frac{\pi}{2}}\right\}$$
$$+ \frac{1}{3!}\left\{A^3\alpha^{3\frac{\pi}{2}} + B^3\beta^{3\frac{\pi}{2}} + C^3\gamma^{3\frac{\pi}{2}} + 3A^2B\alpha^{\pi}\beta^{\frac{\pi}{2}} + 3A^2C\alpha^{\pi}\gamma^{\frac{\pi}{2}} + 3B^2C\beta^{\pi}\gamma^{\frac{\pi}{2}}\right.$$
$$\left. + 3\,AB^2\alpha^{\frac{\pi}{2}}\beta^{\pi} + 3AC^2\,\alpha^{\frac{\pi}{2}}\gamma^{\pi} + 3BC^2\,\beta^{\frac{\pi}{2}}\gamma^{\pi} + 6ABC\,\alpha^{\frac{\pi}{2}}\beta^{\frac{\pi}{2}}\gamma^{\frac{\pi}{2}}\right\}$$
$+$ etc.

where the terms are formed according to the rule of the trinomial theorem, but the order $\alpha$, $\beta$, $\gamma$, must be preserved in each term. And the multinomial theorem is true, provided the above condition is observed.

## Circular Spirals.

*Meaning of* $\alpha^A_w$.

The series $e^A = 1 + A + \frac{A^2}{2!} + \frac{A^3}{3!} +$ may be viewed as having a logarithmic angle or period 0 or more generally $2n\pi$, so that it is expressed more fully by $e^{A\alpha^0}$ or $e^{A\alpha^{2n\pi}}$. Similarly the logarithmic angle or period of $\alpha^A$, that is of

$$e^{A\alpha^{\frac{\pi}{2}}} = 1 + A\alpha^{\frac{\pi}{2}} + \frac{A^2\alpha^{\pi}}{2!} +$$

is $\frac{\pi}{2}$ or more generally $2n\pi + \frac{\pi}{2}$.

By $\alpha^A_w$ is meant $e^{A\alpha^w}$ where the logarithmic angle is $w$, so that

$$\alpha_w^A = e^{A\alpha^w} = 1 + A\alpha^w + \frac{A^2\alpha^{2w}}{2!} + \frac{A^3\alpha^{3w}}{3!} + .$$

**What is the geometrical meaning of $\alpha_w^A$? It is a sector of the logarithmic spiral which has $\alpha$ for axis, $w$ for the angle between the tangent and the radius vector and $A \sin w$ for the angle at the apex.**

**On account of the new element $w$ the quantity may be named a *quinternion*, for when a multiplier is prefixed we have five elements.**

*To prove that* $\alpha_w^A = e^{A\cos w + A\sin w \cdot \alpha^{\frac{\pi}{2}}}$

For $\alpha_w^A = e^{A\alpha^w} = 1 + A\alpha^w + \frac{A^2\alpha^{2w}}{2!} + \frac{A^3\alpha^{3w}}{3!} + ,$

$$= 1 + A\cos w + \frac{A^2\cos 2w}{2!} + \frac{A^3\cos 3w}{3!} +$$

$$+ \left\{ A\sin w + \frac{A^2\sin 2w}{2!} + \frac{A^3\sin 3w}{3!} + \right\} \cdot \alpha^{\frac{\pi}{2}}$$

But $e^{A\cos w + A\sin w \cdot \alpha^{\frac{\pi}{2}}} = e^{A\cos w}\, e^{A\sin w \cdot \alpha^{\frac{\pi}{2}}}$

$$= \left\{1 + A\cos w + \frac{A^2\cos^2 w}{2!} + \right\} \left\{1 + A\sin w \cdot \alpha^{\frac{\pi}{2}} - \frac{A^2\sin^2 w}{2!} + \right\},$$

$$= 1 + A\cos w + \frac{A^2}{2!}(\cos^2 w - \sin^2 w) +$$

$$+ \left\{A\sin w + \frac{A^2}{2!}\, 2\sin w\cos w + \right\} . \alpha^{\frac{\pi}{2}};$$

$$= 1 + A\cos w + \frac{A^2}{2!}\cos 2w +$$

$$+ A\sin w + \frac{A^2}{2!}\sin 2w +$$

therefore $e^{A\alpha^w} = e^{A\cos w + A\sin w \cdot \alpha^{\frac{\pi}{2}}}.$

*To prove that* $\alpha_w^A\,\beta_w^B = e^{A\alpha^w + B\beta^w}.$

Since $\alpha_w^A = e^{A\cos w + A\sin w \cdot \alpha^{\frac{\pi}{2}}}$

and $\beta_w^B = e^{B\cos w + B\sin w \cdot \beta^{\frac{\pi}{2}}}$

$$\alpha_w^A\,\beta_w^B = e^{A\cos w}\, e^{A\sin w \cdot \alpha^{\frac{\pi}{2}}}\, e^{B\cos w}\, e^{B\sin w \cdot \beta^{\frac{\pi}{2}}}$$

$$= e^{A\cos w + B\cos w}\, e^{A\sin w \cdot \alpha^{\frac{\pi}{2}} + B\sin w \cdot \beta^{\frac{\pi}{2}}}$$

$$= e^{(A+B)\cos w}\, e^{\sin w\left\{A \cdot \alpha^{\frac{\pi}{2}} + B \cdot \beta^{\frac{\pi}{2}}\right\}}$$

But $e^{A\alpha^w + B\beta^w} = e^{(A\cos w + A\sin w \cdot \alpha^{\frac{\pi}{2}}) + (B\cos w + B\sin w \cdot \beta^{\frac{\pi}{2}})}$

$$= e^{A\cos w + B\cos w}\ e^{A\sin w \cdot \alpha^{\frac{\pi}{2}} + B\sin w \cdot \beta^{\frac{\pi}{2}}}.$$

Because $e^{A\cos w}$ and $e^{B\cos w}$ are independent of axis, they can be changed from the order in which they occur in the sum of indices.

The meaning of $\alpha_w^A\ \beta_w^B$ is the sector of the spiral which joins the beginning of the former with the end of the latter.

Hence when $\beta = \alpha$,

$$\alpha_w^A\ \alpha_w^B = e^{(A+B)\cos w}\ e^{(A+B)\sin w \cdot \alpha^{\frac{\pi}{2}}}$$

$$= e^{(A+B)\alpha^w}$$

$$= \alpha_w^{A+B}$$

which is the addition theorem for the logarithmic spiral, the two component sectors being in the same plane.

*Exponent of a compound angle.*

We have

$$e^{x\alpha^A\beta^B} = 1 + x\,\alpha^A\beta^B + \frac{x^2}{2!}(\alpha^A\beta^B)^2 + \frac{x^3}{3!}(\alpha^A\beta^B)^3 + ;$$

where $\alpha^A\beta^B$ is expanded as shown above, and $(\alpha^A\beta^B)^2$ is double of the compound angle, $(\alpha^A\beta^B)^3$ is three times the compound angle and so on. It is to be observed that $(\alpha^A\beta^B)^2$ is not in general equal to $\alpha^{2A}\beta^{2B}$.

Let $x = A = B = \frac{\pi}{2}$ and let $\beta$ be identical with $\alpha$, then we have

$$e^{\frac{\pi}{2}\alpha^\pi} = 1 - \frac{\pi}{2} + \left(\frac{\pi}{2}\right)^2 \frac{1}{2!} - .$$

But $e^{\frac{\pi}{2}\alpha^\pi} = e^{-\frac{\pi}{2}}$ and it is also $= \alpha^{\frac{\pi}{2}\alpha^{\frac{\pi}{2}}}$;

$$\text{and thus } e^{-\frac{\pi}{2}} = \alpha^{\frac{\pi}{2}\alpha^{\frac{\pi}{2}}},$$

which is a rational expression for the celebrated equation of Euler

$$\sqrt{-1}^{\sqrt{-1}} = e^{-\frac{\pi}{2}}.$$

By taking logs we obtain

$$\alpha^{\frac{\pi}{2}} \log\left(\alpha^{\frac{\pi}{2}}\right) = -\frac{\pi}{2},$$

that is

$$\frac{\log\left(\alpha^{\frac{\pi}{2}}\right)}{\alpha^{\frac{\pi}{2}}} = \frac{\pi}{2}.$$

*To differentiate $\alpha^A$.*

Since $\alpha^A = e^{A\alpha^{\frac{\pi}{2}}} = \cos A + \sin A \cdot \alpha^{\frac{\pi}{2}}$;

therefore

$$d(a^A) = e^{Aa^{\frac{\pi}{2}}} d\,(Aa^{\frac{\pi}{2}}) = (-\sin A + \cos A \cdot a^{\frac{\pi}{2}})\, dA + \sin A\, da \cdot \bar{a}^{\frac{\pi}{2}}$$

therefore

$$a^A d(Aa^{\frac{\pi}{2}}) = (-\sin A + \cos A \cdot a^{\frac{\pi}{2}}) dA + \sin A\, da \cdot \bar{a}^{\frac{\pi}{2}}$$

But since

$$a^A a^{-A} = 1,$$

$$d(a^A)\, a^{-A} + a^A d\,(a^{-A}) = 0;$$

therefore

$$a^A d(Aa^{\frac{\pi}{2}}) a^{-A} + a^A a^{-A}\, d(-Aa^{\frac{\pi}{2}}) = 0;$$

therefore $$a^A d(Aa^{\frac{\pi}{2}})\, a^{-A} = d(Aa^{\frac{\pi}{2}}).$$

Hence
$$\begin{aligned} d(Aa^{\frac{\pi}{2}}) &= a^{A+\frac{\pi}{2}} dA a^{-A} + \sin A\, da \cdot \bar{a}^{\frac{\pi}{2}} a^{-A} \\ &= dA \cdot a^{\frac{\pi}{2}} + da\,(\sin A \cos A \cdot \bar{a}^{\frac{\pi}{2}} - \sin^2 A \cdot \bar{a}^{\frac{\pi}{2}} a^{\frac{\pi}{2}}) \\ &= dA \cdot a^{\frac{\pi}{2}} + da\,(\sin A \cos A \cdot \bar{a}^{\frac{\pi}{2}} + \sin^2 A \cdot \overline{\bar{a}a}^{\frac{\pi}{2}}) \\ &= \left\{dA \cdot a + da\,(\sin A \cos A \cdot \bar{a} + \sin^2 A \cdot \overline{\bar{a}a}\right\}^{\frac{\pi}{2}} \end{aligned}$$

*To differentiate* $a^A \beta^B$.

$$\begin{aligned} d(a^A\beta^B) &= (da^A)\, \beta^B + a^A d\,(\beta^B), \\ &= a^A d\,(Aa^{\frac{\pi}{2}})\, \beta^B + a^A\beta^B d\,(B\beta^{\frac{\pi}{2}}), \end{aligned}$$

which is not $$= a^A\beta^B \left\{ d(Aa^{\frac{\pi}{2}}) + d(B\beta^{\frac{\pi}{2}}) \right\} \text{ unless } \beta = a.$$

But $$a^A\, \beta^B = e^{Aa^{\frac{\pi}{2}} + B\beta^{\frac{\pi}{2}}}$$

and $$d(a^A\beta^B) = e^{Aa^{\frac{\pi}{2}} + B\beta^{\frac{\pi}{2}}}\, d\,(Aa^{\frac{\pi}{2}} + \dot{B}\beta^{\frac{\pi}{2}}),$$

provided it be understood that in the final terms the order of $a$, $\beta$ be observed.

To differentiate $e^{(Aa + B\beta)^{\frac{\pi}{2}}}$ is more simple, because then we have but one index, not a binomial, and

$$d\left\{e^{(Aa + B\beta)^{\frac{\pi}{2}}}\right\} = e^{(Aa + B\beta)^{\frac{\pi}{2}}} d\left\{ (Aa + B\beta)^{\frac{\pi}{2}} \right\}.$$

## Hyperbolic Trigonometry.

*Meaning of the equation*

$$ha^A = \cosh A + \sinh A \cdot a^{\frac{\pi}{2}}.$$

The expression $a^A$, when no period is expressed, is understood to have the period $\frac{\pi}{2}$; in other words the area $\frac{A}{2}$ is bounded by a circular arc. Let $ha^A$ denote the same when the bounding arc is the equilateral hyperbola (fig. 10). Then the rectangular components $OM$ and $MQ$ of the hyperbolic versor which has the axis $a$ and the area $\frac{A}{2}$ are commonly denoted by $\cosh A$ and $\sinh A$, so that

$$ha^A = \cosh A + \sinh A \cdot a^{\frac{\pi}{2}}$$

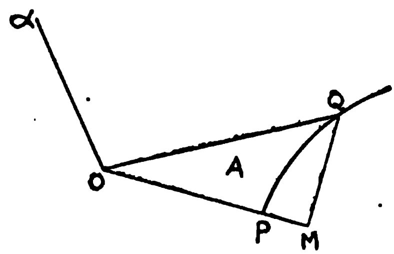


FIG. 10.

The hyperbolic versor $ha^A$ is equivalent to the multiplier $\cosh A$ together with the circular versor $\sinh A \cdot a^{\frac{\pi}{2}}$.

*To prove that* $ha^A = he^{Aa^{\frac{\pi}{2}}}$.

We have
$$ha^A = \cosh A + \sinh A \cdot a^{\frac{\pi}{2}},$$
$$= 1 + \frac{A^2}{2!} + \frac{A^4}{4!} +$$
$$+ \left(A + \frac{A^3}{3!} + \right) \cdot a^{\frac{\pi}{2}}$$

This is an essentially different expansion from the circular. It may be denoted by $h\, e^{Aa^{\frac{\pi}{2}}}$, and it differs from that for $e^{Aa^{\frac{\pi}{2}}}$ in having $a^{\frac{\pi}{2}}\, a^{\frac{\pi}{2}} = 1$.

Similarly
$$ha^{-A} = \cosh A - \sinh A \cdot a^{\frac{\pi}{2}},$$
$$= h\, e^{-Aa^{\frac{\pi}{2}}}.$$

*To compare* $ha^A$ *with* $e^{Aa^{\pi}}$.

$$e^{Aa^{\pi}} = \cosh A + \sinh A \cdot a^{\pi},$$
$$= \cosh A + a^{\frac{\pi}{2}} \sinh A \cdot a^{\frac{\pi}{2}};$$

that is
$$e^{(Aa^{\frac{\pi}{2}})a^{\frac{\pi}{2}}} = \cosh A + a^{\frac{\pi}{2}} \sinh A \cdot a^{\frac{\pi}{2}};$$

therefore $$\cosh A = \cos\left(A a^{\frac{\pi}{2}}\right),$$

and $$a^{\frac{\pi}{2}} \sinh A = \sin\left(A a^{\frac{\pi}{2}}\right).$$

Also $$ha^{-A} = \cosh A - \sinh A \cdot a^{\frac{\pi}{2}},$$
$$= \cos\left(A a^{\frac{\pi}{2}}\right) - a^{\frac{\pi}{2}} \sin\left(A a^{\frac{\pi}{2}}\right) \cdot a^{\frac{\pi}{2}}.$$

*To find the value of $ha^A\, h\beta^B$, the analogue of $a^A \beta^B$.*

We have $$ha^A = \cosh A + \sinh A \cdot a^{\frac{\pi}{2}},$$

and $$h\beta^B = \cosh B + \sinh B \cdot \beta^{\frac{\pi}{2}};$$

therefore $$ha^A h\beta^B = \cosh A \cosh B + \cosh A \sinh B \cdot \beta^{\frac{\pi}{2}}$$
$$+ \cosh B \sinh A \cdot a^{\frac{\pi}{2}} + \sinh A \sinh B \cdot a^{\frac{\pi}{2}} \beta^{\frac{\pi}{2}}.$$

The problem is reduced to finding the value of $a^{\frac{\pi}{2}} \beta^{\frac{\pi}{2}}$. Now for a plane, in which case $a = \beta$, we have
$$ha^A\, ha^B = \cosh A \cosh B + \sinh A \sinh B$$
$$+ \left\{\cosh A \sinh B \cdot a + \cosh B \sinh A \cdot a\right\}^{\frac{\pi}{2}}$$
from which it appears that the second term of the *cosh* for space is $\sinh A \sinh B \cos a\beta$. The term in *Sinh* must be of the form
$$x \sinh A \sinh B \sin a\beta \cdot \overline{a\beta},$$
the value of $x$ to be determined by the condition that $\cosh^2 - \sinh^2 = 1$.

Now
$$\cosh^2 = \cosh^2 A \cosh^2 B + \sinh^2 A \sinh^2 B \cos^2 a\beta$$
$$+ 2 \cosh A \cosh B \sinh A \sinh B \cos a\beta.$$
and $$\sinh^2 = \cosh^2 A \sinh^2 B + \cosh^2 B \sinh^2 A$$
$$+ 2 \cosh A \cosh B \sinh A \sinh B \cos a\beta$$
$$+ x^2 \sinh^2 A \sinh^2 B \sin^2 a\beta.$$
and $$\cosh^2 - \sinh^2 = \cosh^2 A\,(\cosh^2 B - \sinh^2 B)$$
$$- \sinh^2 A \left\{\cosh^2 B - \sinh^2 B\,(\cos^2 a\beta - x^2 \sin^2 a\beta)\right\},$$
which is equal to 1, if $x^2 = -1$, or $x = \sqrt{-1}$.

Hence $$\cosh a^A \beta^B = \cosh A \cosh B + \sinh A \sinh B \cos a\beta \qquad (1)$$

and $$\operatorname{Sinh} a^A \beta^B = \Big\{\cosh A \sinh B \cdot \beta + \cosh B \sinh A \cdot a$$
$$+ \sqrt{-1} \sinh A \sinh B \sin a\beta \cdot \overline{a\beta}\Big\}. \qquad (2)$$

Equation (1) is the fundamental theorem in hyperbolic non-Euclidian geometry. Equation (2) gives the complementary theorem, and we propose to investigate its geometrical meaning. Guided by thé analogy to the circular sectors we conclude that equation (1) suffices to determine the amount of hyperbolic sector of the product, while equation (2) serves to determine the plane of the sector. How can the expression in (2) determine a plane? Compound (fig. 11) *cosh A sinh B* · $\beta$ with *cosh B sinh A* · $\alpha$ and from the extremity $P$ describe a circle with radius *sinh A sinh B sin* $\alpha\beta$ in the plane of $OP$ and the perpendicular $\overline{\alpha\beta}$. The positive tangent $OT$, drawn from $O$ to the circle has the direction of the perpendicular to the plane.

This may be readily verified in the case of the product of equal sectors.

Let
$$\alpha^A = x + y \cdot \alpha^{\frac{\pi}{2}}$$
$$\beta^A = x + y \cdot \beta^{\frac{\pi}{2}}$$
then according to the rule for the product in space
$$\alpha^A\beta^A = x^2 + y^2 \cos \alpha\beta$$
$$+ \left\{ xy(\alpha + \beta) + \sqrt{-1}\, y^2 \sin \alpha\beta \cdot \overline{\alpha\beta} \right\}^{\frac{\pi}{2}}$$

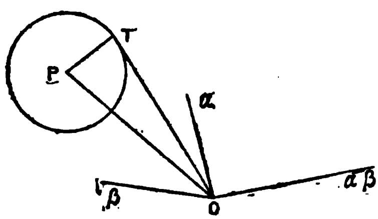


FIG. 11.

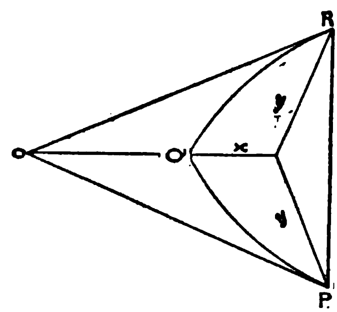


FIG. 12.

Suppose that the straight line $PR$ (fig. 12) joining the extremities of the arcs is the chord of the product; it is symmetrical with respect to the axis $\overline{\alpha\beta}$. Then
$$\sinh \frac{\alpha^A\beta^A}{2} = \tfrac{1}{2}\sqrt{2y^2 + 2y^2 \cos \alpha\beta} = \frac{y}{\sqrt{2}}\sqrt{1 + \cos \alpha\beta};$$
therefore
$$\cosh \frac{\alpha^A\beta^A}{2} = \sqrt{1 + \frac{y^2}{2}(1 + \cos \alpha\beta)};$$
therefore by the rule for the plane, which is known to be true,
$$\cosh \alpha^A\beta^A = \frac{y^2}{2}(1 + \cos \alpha\beta) + 1 + \frac{y^2}{2}(1 + \cos \alpha\beta),$$
$$= y^2(1 + \cos \alpha\beta) + 1,$$
$$= y^2 + 1 + y^2 \cos \alpha\beta,$$
$$= x^2 + y^2 \cos \alpha\beta.$$

But this last is the value given above by the rule found for space.

*Prosthaphaeresis in hyperbolic trigonometry.*

We have $\cosh \alpha^A\beta^B = \cosh A \cosh B + \sinh A \sinh B \cos \alpha\beta$;

and $$\text{Sinh}\, \alpha^A\beta^B = \left\{\cosh A \sinh B \cdot \beta + \cosh B \sinh A \cdot \alpha + \sqrt{-1}\, \sinh A \sinh B \sin \alpha\beta \cdot \overline{\alpha\beta}\right\}^{\frac{\pi}{2}}$$

By putting in $-\sinh B$ instead of $\sinh B$ we get

$$\cosh \alpha^A\beta^{-B} = \cosh A \cosh B - \sinh A \sinh B \cos \alpha\beta;$$

and $$\text{Sinh}\, \alpha^A\beta^{-B} = -\cosh A \sinh B \cdot \beta + \cosh B \sinh A \cdot \alpha - \sqrt{-1}\sinh A \sinh B \sin \alpha\beta \cdot \overline{\alpha\beta}.$$

Therefore $\cosh \alpha^A\beta^B + \cosh \alpha^A\beta^{-B} = 2 \cosh A \cosh B$;

$$\cosh \alpha^A\beta^B - \cosh \alpha^A\beta^{-B} = 2 \sinh A \sinh B \cos \alpha\beta;$$

$$\text{Sinh}\, \alpha^A\beta^B + \text{Sinh}\, \alpha^A\beta^{-B} = 2 \cosh B \sinh A \cdot \alpha;$$

$$\text{Sinh}\, \alpha^A\beta^B - \text{Sinh}\, \alpha^A\beta^{-B} = 2 \cosh A \sinh B \cdot \beta + 2\sqrt{-1}\sinh A \sinh B \sin \alpha\beta \cdot \overline{\alpha\beta}.$$

*To prove that* $h\alpha^A h\beta^B = h\, e^{A\alpha^{\frac{\pi}{2}} + B\beta^{\frac{\pi}{2}}}$.

Since $$h\alpha^A = 1 + A\alpha^{\frac{\pi}{2}} + \frac{A^2\alpha^{2\frac{\pi}{2}}}{2!} + \frac{A^3\alpha^{3\frac{\pi}{2}}}{3!} +,$$

and $$h\beta^B = 1 + B\beta^{\frac{\pi}{2}} + \frac{B^2\beta^{2\frac{\pi}{2}}}{2!} + \frac{B^3\beta^{3\frac{\pi}{2}}}{3!} +;$$

$$\begin{aligned} h\alpha^A h\beta^B = 1 &+ A\alpha^{\frac{\pi}{2}} + \frac{A^2\alpha^\pi}{2!} + \frac{A^3\alpha^{3\frac{\pi}{2}}}{3!} + \\ &+ B\beta^{\frac{\pi}{2}} + AB\,\alpha^{\frac{\pi}{2}}\beta^{\frac{\pi}{2}} + \frac{A^2B}{2!}\alpha^\pi\beta^{\frac{\pi}{2}} + \\ &+ \frac{B^2\beta^\pi}{2!} + \frac{AB^2}{2!}\alpha^{\frac{\pi}{2}}\beta^\pi + \\ &+ \frac{B^3}{3!}\beta^{3\frac{\pi}{2}} + \\ = 1 &+ (A\alpha^{\frac{\pi}{2}} + B\beta^{\frac{\pi}{2}}) + \frac{(A\alpha^{\frac{\pi}{2}} + B\beta^{\frac{\pi}{2}})^2}{2!} + \\ = h&e^{A\alpha^{\frac{\pi}{2}} + B\beta^{\frac{\pi}{2}}}. \end{aligned}$$

The expansion is the same as for the product of circular sectors, excepting that we have

$$\alpha^{\frac{\pi}{2}}\beta^{\frac{\pi}{2}} = \cos \alpha\beta + \sqrt{-1}\sin \alpha\beta \cdot \overline{\alpha\beta}^{\frac{\pi}{2}}$$

and (as a special case) $\alpha^\pi = \beta^\pi = 1.$

## Hyperbolic Spirals.

*To investigate the meaning of $ha_w^A$ the analogue of $a_w^A$.*

We must have $h\,a_w^A = he^{A\cosh w}\, he^{A\sinh w\cdot a^{\frac{\pi}{2}}}$,

$$= \left(1 + A\cosh w + \frac{A^2}{2!}\cosh^2 w + \frac{A^3}{3!}\cosh^3 w + \right)$$

$$\times \left(1 + A\sinh w\cdot a^{\frac{\pi}{2}} + \frac{A^2}{2!}\sinh^2 w + \frac{A^3}{3!}\sinh^3 w\cdot a^{\frac{\pi}{2}} + \right)$$

$$= 1 + A\cosh w + \frac{A^2}{2!}(\cosh^2 w + \sinh^2 w) + \frac{A^3}{3!}\left\{\cosh^3 w + 3\cosh w\sinh^2 w\right\} +$$

$$+ \left\{A\sinh w + \frac{A^2}{2!}2\cosh w\sinh w + \frac{A^3}{3!}\left\{3\cosh^2 w\sinh w + \sinh^3 w\right\} + \right\}\cdot a^{\frac{\pi}{2}}$$

$$= 1 + A(\cosh w + \sinh w\cdot a^{\frac{\pi}{2}}) + \frac{A^2}{2!}(\cosh w + \sinh w\cdot a^{\frac{\pi}{2}})^2 + \frac{A^3}{3!}(\cosh w + \sinh w\cdot a^{\frac{\pi}{2}})^3 +$$

$$= 1 + A\cosh w + \frac{A^2}{2!}\cosh 2w + \frac{A^3}{3!}\cosh 3w +$$

$$+ \left\{A\sinh w + \frac{A^2}{2!}\sinh 2w + \frac{A^3}{3!}\sinh 3w + \right\}\cdot a^{\frac{\pi}{2}}$$

$$= 1 + Aa^w + \frac{A^2}{2!}a^{2w} + \frac{A^3}{3!}a^{3w} + .$$

It follows as in the case of the circular spirals, that

$$ha_w^A\, h\beta_w^B = he^{Aa^w + B\beta^w}$$

$$= e^{A\cosh w\ +\ B\cosh w}\, ha^{A\sinh w}\, h\beta^{B\sinh w}\ .$$

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**The spectroheliograph of the Kenwood Astro-physical Observatory, Chicago, and results obtained in the study of the sun.** By George E. Hale, Director Kenwood Observatory, University of Chicago, Chicago, Ill.

[Abstract.]

The spectroheliograph is an instrument devised by the author for photographing sun-spots, faculæ, the chromosphere and prominences in a single picture of the sun. It consists of a large diffraction spectroscope (attached to the twelve-inch equatorial of the Kenwood Observatory) having two movable slits, one at the focus of the collimator and one at the focus of the observing telescope. These are so connected by a

system of levers to a new form of clepsydra that they can be made to move at uniform velocities bearing a constant ratio to each other. As the first slit moves across the sun's image the second slit moves at such a rate that the K line in the fourth order spectrum of the grating constantly passes through it, and falls upon a photographic plate. As it was discovered photographically at the Kenwood Observatory in 1891 that H and K are both reversed in all prominences and faculæ, it follows that photographs of these objects can readily be obtained with the spectroheliograph. In taking a photograph, after K has been adjusted to pass through the second slit, the sun's image at the focus of the equatorial is covered by a diaphragm exactly equalling it in size, and as the slit moves across, the chromosphere and prominences around the entire circumference are photographed on the plate. When the slit reaches the end of its course the diaphragm is removed, and the slit made to move back across the sun's image at a greater speed. Both spots and faculæ are thus obtained on the same plate with the chromosphere and prominences. The faculæ are well shown in even the brightest parts of the sun's surface, where they have up to the present been invisible. Daily photographs of solar phenomena are thus obtained at the Kenwood Observatory and on them some remarkable curved forms of faculæ have been discovered. Since the first application of photography by the author (in Apr., 1891) to the study of the ultra-violet spectrum of the solar prominences, twenty-eight lines have been discovered in this part of the spectrum.

[This paper was illustrated by lantern pictures; and photographs (paper prints) of sun-spots, faculæ, chromosphere, prominences and spectra were exhibited.]

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MODELS AND MACHINES FOR SHOWING CURVES OF THE THIRD DEGREE. By ANDREW W. PHILLIPS, Ph.D., Prof. of Math., Yale University, New Haven, Conn.

[ABSTRACT.]

1. The formation of curves of the third degree by the intersection of two surfaces.

2. Exhibition of the surfaces

$$z = xy^2 + ey \text{ and } z = ax^3 + bx^2 + cx + d$$

so constructed, that they may be deformed to represent different values of the *constant* coëfficients, and also to intersect and form the curves

$$xy^2 + ey = ax^3 + bx^2 + cx + d.$$

3. A machine so constructed, that by its aid any one of the following four forms (Newton's forms) may be readily plotted.

$$xy^2 + ey = ax^3 + bx^2 + cx + d$$
$$xy = ax^3 + bx^2 + cx + d$$
$$y^2 = ax^3 + bx^2 + cx + d$$
$$y = ax^3 + bx^2 + cx + d$$

This last machine consists of a simple means of applying the principles involved in (2) to the plotting of curves.

4. Exhibition of *cones* of the third degree partially immersed in a tank of colored liquid to show the various curves of intersection.

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Least square fallacies. By Prof. Truman Henry Safford, Williams College, Williamstown, Mass.

[Abstract.]

In applying the method of least squares to physical problems, it is necessary not to overlook the essential conditions of the method, as expounded by Gauss.

These are:

1. The series of observations must be free from constant error; or, in other words, all the unknowns must be employed in the equations.

2. The casual errors must be distributed according to the law of error on which the method is based. If such distribution is imperfect, the method of least squares will give imperfect results.

3. Consequently the "modulus of precision" must be the same for all the observations; or the proper weight must be assigned to each observation.

4. There must not be mistakes in the series; discontinuous errors must be carefully avoided.

As observations and experiments become more and more precise, we usually find that these conditions are more and more nearly fulfilled. The law of error is best considered as resulting from the combination of elementary very minute errors, each of small amount and each as likely to be positive as negative; and no one of these elementary errors must largely exceed the others in amount.

The process of making more and more precise observations consists in avoiding, one after another, sources of minute errors which seem to exceed others in amount; so that there is a constant tendency to bring their values into that relation to each other which the law requires. Good administration of an observatory, for instance, requires that the older astronomers, or the director, shall continually watch over the work of the younger and less experienced observers, to provide that they shall not fall either into mistakes or into elementary errors of small amount, which however, are larger than they ought to be. And one of the most obvious marks of a bad series of observations is the frequency of mistakes or of casual errors which cannot be readily distinguished from mistakes.

The following are some of the common practices which arise from fallacious reasoning on this subject. They are taken mostly from astronomical or geodetic practice; and are found in collections of observations and results which frequently possess very high authority.

Time observations with the transit instrument have frequently been reduced without weighting the observations. When one of the stars is very near the pole, its modulus of precision is less. When this fact is disregarded, the errors will not be distributed as the method requires. The weight of one's own observation is sometimes over-estimated. We suppose that we know more about these errors than we do; and that the systematic or casual differences which we find between our results and those of our competitors are due to them and not to us.

The weight of old and rough observations is often overstated. We have so long been in the habit of looking up with reverence to the illustrious men who made them that we give them more credit than they deserve.

Weights are assigned without a careful study of the results, more by a general feeling than by any intellectual process. In one well-known case, the astronomer who made such a mistake acknowledged that he had given eye-and-ear observations the weight of chronographic.

In stating definitive results for clock corrections, it is a common practice to omit polar stars. When these last have been properly weighted, the results of a least square solution of the equations are *the most probable.*

If, then, the polar stars are omitted, and the mean of separate results from the rest taken, whether weighted or not, this mean will be *less probable* than the other. Usually it happens that the two differ but little; the labor then, of taking such a final average is simply lost. It is sometimes allowable in problems which do not lead to uniform methods to state the second results as a check; but in this problem there is no need of such a control.

Computers frequently do not follow Gauss's advice to employ as accurate values of the unknowns as can be conveniently obtained, and to make the least square solution furnish only corrections to these values. By this advice, errors of calculation are most readily avoided, and the real need of employing least squares in preference to a simpler process can be better estimated. Oftentimes it is quite needless; that is, its employment saves only the labor of making and reducing a very few additional observations. In fact, one great use of the method is to render itself superfluous by leading to better observations.

Mechanical computers are too apt to think that the especial mechanism which they use has some "magic quality," and can convert bad observations into good.

Probable errors, and especially probable errors of results, are a fertile source of blunder in computation.

The so-called criteria for rejecting doubtful observations are less employed than they were some years ago, and with propriety. Their work is now done by greater care to avoid mistakes. A good observer needs no such criterion; a bad one cannot by its use transform his observations into good ones.

A great series of observations has adopted the formula

$$\epsilon = \frac{\Sigma e}{n\sqrt{n-1}}$$

for stating the probable error of its results.

It is only applicable when $n$ is very large; when a result depends upon a few observations, we must substitute the formula

$$\epsilon = \frac{e_0}{\sqrt{n}}$$

using for $e_0$ not the precarious single value

$$\frac{\Sigma e}{\sqrt{n(n-1)}}$$

but an average derived from a great many similar cases. In the series to which I have referred, $n$ is very often no more than 3; and the probable error of each result is mechanically computed from the three or more discrepancies of the observations which furnish that result.

This case is an extreme one; but we often find similar but less calamitous instances. In all cases, the probable error of observations should be derived from at least a hundred discrepancies if possible.

An additional fallacy arises when the probable error of results is stated. Experience shows that in almost all cases some new element must be considered. For example, the probable error of a single star transit includes not only that arising from the discrepancies of the wires, but the variation from star to star of personal equation; so that it is erroneous to calculate the weight of a transit from the wire discrepancies only. Again, a batch of stars well selected usually gives a smaller probable error for the time by their separate results, than a comparison of a dozen cases when similar batches are observed side by side by two men on different nights. Here we have to reckon with variation of personal equation or perhaps unnoticed instrumental changes from night to night. The distinction between *internal* and *external* probable error is one which must be very carefully observed.

In a longitude operation, for example, the correct practice would be to assign the probable error of the resulting longitude from long experience of the same two observers with the same two instruments; and to enlarge it with judgment for their earlier and less accurate operations. But even then, and certainly most commonly, do we find that the adjustment of a network of longitudes gives us a somewhat larger probable error than we should have expected.

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LINEO-LINEAR VECTOR FUNCTIONS. By Prof. ARTHUR S. HATHAWAY, Rose Polytechnic Institute, Terre Haute, Ind.

[ABSTRACT.]

LET $\Phi\rho\sigma$ be a linear vector function in each $\rho$ and $\sigma$. In its utmost generality, $\Phi$ involves nine arbitrary vector constants, $\Phi\alpha\alpha$, $\Phi\alpha\beta$, etc., or twenty-seven arbitrary scalar constants of the form

$$S\tau\varphi\rho\sigma \; [\tau, \rho, \sigma = \alpha, \beta, \gamma$$

in all possible permutations].

The successive conjugates of $\Phi$ as to $\rho$ and $\sigma$ form derived functions $K_1\Phi$, $K_2\Phi$, $K_3\Phi$, . . . with the same scalar constants as $\Phi$, viz.:

$$S\tau\Phi\rho\sigma = S\rho K_1\Phi\tau\sigma = S\sigma K_2\Phi\rho\tau = S\tau K_3\Phi\sigma\rho, \text{ etc.}$$

The symbols $K_1$, $K_2$, $K_3$ have the same laws of combination as the transpositions $(\tau\rho)$, $(\tau\sigma)$, $(\rho\sigma)$, while $K_1K_2$, $K_2K_1$ correspond to the cyclic substitutions $(\tau\rho\sigma)$, $(\tau\sigma\rho)$. Hence

$$1 = K_1^2 = K_2^2 = K_3^2 = \overline{K_1K_2}^3 = \overline{K_2K_1}^3$$

$$K_1K_2 = K_2K_3 = K_3K_1 = \overline{K_2K_1}^2.$$

Besides these equations and others that may be derived from them by the use of the associative principle, there are relations that hold for special forms of $\varphi$.

Let $[\varphi_1, \ldots]$ $[\varphi_2, \ldots]$ $[\varphi_3, \ldots]$ be the systems of functions that give $K_1 = 1$, $K_2 = 1$, $K_3 = 1$ respectively. A function from one of these three systems has but two conjugate functions, which belong to the other two systems. Since $\varphi_3\rho\sigma = \varphi_3\sigma\rho$, therefore functions of these forms involve only six vector constants, or eighteen scalar constants. The system of functions $[\varphi, \ldots]$ that are common to two of these systems belongs also to the third system, and each gives

$$K_1 = K_2 = K_3 = 1.$$

Such a *self-conjugate* function involves only ten scalar constants, or the three vectors $\varphi aa$, $\varphi\beta\beta$, $\varphi\gamma\gamma$, and $Sa\varphi\beta\gamma$. Its canonical form is

$$axx' + \beta yy' + \gamma zz' + a[a(yz' + y'z) + \beta(zx' + x'z) + \gamma(xy' + x'y)],$$

$x = Sa\rho$, $x' = Sa\sigma$, etc. Putting $\sigma = \rho$ and operating with $S\cdot\rho$ we obtain $x^3 + y^3 + z^3 + 6axyz$, the canonical form of the homogeneous cubic in three variables.

Let $[\varphi_1', \ldots]$, $[\varphi_2', \ldots]$ $[\varphi_3', \ldots]$ be the systems of functions that give $K_1 = -1$, $K_2 = -1$, $K_3 = -1$, respectively. A function from one of these three systems has but two conjugate functions, which belong to the other two systems. From the ordinary theory, we have $\varphi_1'\rho\sigma = V\rho\varphi\sigma$, $\varphi_2'\rho\sigma = V\sigma\varphi\rho$, where $\varphi\rho$ is a linear vector function of $\rho$. Hence $\varphi_3' = \varphi V\rho\sigma$, or, in words: *If $\varphi\rho\sigma$ change sign when $\rho$, $\sigma$ are interchanged, it is a linear vector function of $V\rho\sigma$.* (For examples, see Tait, Art. 159). The functions $[\varphi', \ldots]$ that are common to two of these systems belong also to the third system and are of the form $aV\rho\sigma$. They give $K_1 = K_2 = K_3 = -1$.

Let $[\varphi_1, \ldots]$ be the system of functions that give $K_1K_2 = 1$. Then also $K_2K_1 = 1$, $K_1 = K_2 = K_3$. This *primary* function, $\varphi_1$, may be resolved into the sum $\varphi_1 + \varphi_1'$ in only one way.

Let $[\varphi_w, \ldots]$, wherein $w$ is a primitive cube root of unity, be the system of functions that give $K_1K_2 = w$. Then also,

$$K_2K_1 = w^2, K_1 = w^2K_2 = wK_3.$$

The conjugate of $\varphi_w$ belongs to the conjugate system $[\varphi_{w^2}, \ldots]$. Any function $\varphi$ can be resolved into the two self-conjugate primary parts $\varphi_1 \varphi_1'$, and the two conjugate imaginary, non-primary, parts $\varphi_w, \varphi_{w^2}$ in only one way, viz.:

$$\varphi = L\varphi + M\varphi + A\varphi + D\varphi,$$

wherein

$$L = \tfrac{1}{6}(1 + K_1K_2 + K_2K_1 + K_1 + K_2 + K_3),$$
$$M = \tfrac{1}{6}(1 + K_1K_2 + K_2K_1 - K_1 - K_2 - K_3),$$
$$A = \tfrac{1}{3}(1 + w^2K_1K_2 + wK_2K_1),$$
$$D = \tfrac{1}{3}(1 + wK_1K_2 + w^2K_2K_1),$$

we add,

$$B = \tfrac{1}{3}(K_1 + wK_2 + w^2K_3),$$
$$C = \tfrac{1}{3}(K_1 + w^2K_2 + wK)^3.$$

These six operations, just written, are a transformation of 1, $K_1$, $K_2$, $K_3$, $K_1K_2$, $K_2K_1$, and have the following multiplication table:

| | $L$ | $M$ | $A$ | $B$ | $C$ | $D$ |
|---|---|---|---|---|---|---|
| $L$ | $L$ | 0 | 0 | 0 | 0 | 0 |
| $M$ | 0 | $M$ | 0 | 0 | 0 | 0 |
| $A$ | 0 | 0 | $A$ | $B$ | 0 | 0 |
| $B$ | 0 | 0 | 0 | 0 | $A$ | $B$ |
| $C$ | 0 | 0 | $C$ | $D$ | 0 | 0 |
| $D$ | 0 | 0 | 0 | 0 | $C$ | $D$ |

Hence, the linear form $aA + bB + cC + dD$ and the matrix $\begin{vmatrix} a & b \\ c & d \end{vmatrix}$ may be regarded as equivalent symbols (Tait, Chap. VI (C)).

The problem of transforming these operations into new ones $L_1$, $L_2$, $L_3$, that have the same relations as $K_1$, $K_2$, $K_3$, is capable of solution in an infinite number of ways, thus:

$$L_1 = L - M + (a + a')A + (b + b')B + (c + c')C - (a + a')D.$$
$$L_2 = L - M + (wa + w^2a')A + (wb + w^2b')B + (wc + w^2c')C - (wa + wa')D.$$
$$L_3 = L - M + (w^2a + wa')A + (w^2b + wb')B + (w^2c + wc')C - (wa + wa')D.$$

where $$a^2 + bc = a'^2 + b'c' = 0,$$
$$2aa' + bc' + b'c = 1.$$

In particular, if $L_1L_2 = K_1K_2$, $L_2L_1 = K_2K_1$, then $L_1 = L - M + bB + cC$, etc., wherein $bc = 1$ or $L_1 = \frac{1}{3}(1 + b + c)K_1 + \frac{1}{3}(1 + wb + w^2c)K_2 + \frac{1}{3}(1 + w^2b + wc)K_3$.

If we put $\varphi\rho\sigma = \Sigma Vq_1\rho q_2\sigma q_3$, then the transpositions (12) (23) (31) on the subscripts of the $q$'s are values of $L_1$, $L_2$, $L_3$, giving $L_1L_2 = K_1K_2$, etc. Hence $\Sigma Vq_2\rho q_1\sigma q_3$ may be expressed in terms of the three vectors $\Sigma Vq_2\sigma q_3\rho q_1$, $\Sigma Vq_3\sigma q_1\rho q_2$, $\Sigma Vq_1\sigma q_2\rho q_3$, with invarient coëfficients.

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CONCERNING A CONGRUENCE-GROUP OF ORDER, 360 CONTAINED IN THE GROUP OF LINEAR FRACTIONAL SUBSTITUTIONS. By Prof. E. HASTINGS MOORE, University of Chicago, Chicago, Ill.

[ABSTRACT.]

THE general group is that of the substitutions
$$\left(w, \frac{aw+b}{cw+d}\right), \ (ad - bc = 1),$$
where $a$, $b$, $c$, $d$ are any quantities satisfying the relation $ad - bc = 1$; the order is $\infty$. An included group is obtained by limiting $a$, $b$, $c$, $d$, to quantities of the form
$$\mu + \nu\sqrt{-1}$$
where $\nu$ and $\mu$ are integers; the order is $\infty$. The group in question, of order 360, is obtained by considering two substitutions
$$\left(w, \frac{aw+b}{cw+d}\right), \ \left(w, \frac{a'w+b'}{c'w+d'}\right),$$
of this last group as identical, when
$$\begin{array}{lll} a \equiv a' & \text{or} \quad -a \equiv a' & \text{(mod. 3)} \\ b \equiv b' & \quad\quad -b \equiv b' & \\ c \equiv c' & \quad\quad -c \equiv c' & \\ d \equiv d' & \quad\quad -d \equiv d'. & \end{array}$$
understanding
$$\mu + \nu\sqrt{-1} \equiv \mu' + \nu'\sqrt{-1} \quad \text{(mod. 3)}$$
when
$$\mu \equiv \mu' \quad \nu \equiv \nu' \quad \text{(mod. 3)}.$$

In the paper the 360 substitutions are exhibited multiplicatively in terms of the two types of substitutions,
$$G = \left(w, \frac{-1}{w}\right), \ F_t = \left(w, \frac{w+t}{1}\right).$$

The group-property for the substitutions in this form is shown to depend (on the immediate relations
$$G^2 = 1, \ F_t F_{t^1} = F_{t+t^1}, \ (F_t)^3 = 1,$$
where $1 = \left(w, \frac{w}{1}\right)$, and) on a relation of the form
$$GF_{s_1} \ GF_{s_2} \ GF_{s_3} \ GF_{s_4} \ GF_{s_5} = 1,$$
where the quantities $s_1 \ldots s_5$ are uniquely determined by any two of them.

THE SECULAR MOTION OF A FREE MAGNETIC NEEDLE. By L. A. BAUER, U. S. Coast and Geodetic Survey, Washington, D. C. [To be printed in Amer. Meteor. Journ.]

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EUROPEAN OBSERVATIONS. By J. A. BRASHEAR, Allegheny, Pa.

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ON THE CONFLICT OF OBSERVATION WITH THEORY, AS TO THE EARTH'S ROTATION. By S. C. CHANDLER, Cambridge, Mass.

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LATITUDE OF THE SAYRE OBSERVATORY. By Prof. C. L. DOOLITTLE, South Bethlehem, Pa.

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LIST OF THIRTY NEW PROPER MOTION STARS. By C. L. DOOLITTLE, South Bethlehem, Pa.

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THERMAL ABSORPTION IN THE SOLAR ATMOSPHERE. By EDWIN B. FROST, Hanover, N. H. [To be printed in Astronomische Nachrichten ]

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FORMS OF SOLAR FACULÆ. By GEORGE E. HALE, Chicago, Ill.

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ON THE INTERSECTION OF AN EQUILATERAL HYPERBOLA AND THE SIDES OF A PLANE TRIANGLE. A QUESTION IN TRILINEARS. By Prof. WILLIAM HOOVER, Ohio University, Athens, Ohio.

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ELECTRIC LIGHTS FOR ASTRONOMICAL INSTRUMENTS. By Prof. JEFFERSON E. KERSHNER, Lancaster, Pa. [To be printed in Astronomy and Astro-Physics.]

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ON THE DISCRIMINATORS OF THE DISCRIMINANT OF AN ALGEBRAIC EQUATION. By Prof. MANSFIELD MERRIMAN, Lehigh Univ., South Bethlehem, Pa.

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ON THE CONSTRUCTION OF A PRIME VERTICAL TRANSIT INSTRUMENT FOR THE DETERMINATION OF THE LATITUDE OF HARVARD COLLEGE OBSERVATORY. By Prof. W. A. ROGERS, Colby Univ., Waterville, Me.

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DIFFERENTIAL FORMULÆ FOR ORBIT CORRECTIONS. By Prof. T. H. SAFFORD, Williams College, Williamstown, Mass.

PROPER MOTION OF EIGHTY-NINE STARS WITHIN 10° OF THE NORTH POLE, WITH REMARKS ON THE PRESENT STATE OF THE PROBLEM OF SOLAR MOTION. By Prof. T. H. SAFFORD, Williams College, Williamstown, Mass.

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METEOROLOGICAL OBSERVATIONS MADE IN APRIL 1890, 1891, 1892, IN THE TOTALITY PATH OF THE ECLIPSE OF 1893, APRIL 16. By Prof. DAVID TODD, Amherst College, Amherst, Mass. [To be printed in Amer. Journ. Sci., Oct. and Nov., 1892.]

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INCREASE IN CONSTANT FOR ADDITION, IN TESTING FOR INTEGRAL VALUES IN THE EQUATION OF QUARTER-SQUARES. By JAS. D. WARNER, Brooklyn, N. Y.

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PRACTICAL RULES FOR TESTING WHETHER A NUMBER IS DIVISIBLE BY 7 OR ANY OTHER SMALL PRIME; AND IF NOT DIVISIBLE, TO ASCERTAIN THE REMAINDER. By JAS. D. WARNER, Brooklyn, N. Y.

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ON THE GENERAL PROBLEM OF LEAST SQUARES. By R. S. WOODWARD, U. S. C. & G. Survey, Washington, D. C. [To be printed in Annals of Mathematics.]

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THE ICED-BAR BASE APPARATUS OF THE U. S. COAST AND GEODETIC SURVEY. By R. S. WOODWARD, U. S. C. and G. Survey, Washington, D. C.

## SECTION B.

# PHYSICS.

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# ADDRESS

BY

# BENJAMIN F. THOMAS,

VICE PRESIDENT, SECTION B.

## *TECHNICAL EDUCATION IN COLLEGES AND UNIVERSITIES.*

THE training of young men for the several so-called practical vocations of life has come to form a considerable part of the work done by our colleges and universities, a work in which the members of this section have no small part. I have therefore thought it well to ask your attention to a few points impressed upon me by experience and observation, feeling sure that you have had like experiences, and hoping that out of our discussion of them, mutual help may come, and the work in which we are engaged be advanced by our joint influence and action.

It is not my purpose to review the history of technical education, to prove the need of it, or to discuss its commercial or educational value. It would be interesting to trace the struggle over the introduction of scientific studies into college courses, and their slow elevation to the commanding position they now hold. No less interesting is the change in sentiment respecting the teaching of the applications of science. It is not yet a decade since the contempt felt by the devotees of pure science for those who seek to put her truths to some use, was expressed before this section. Even within the past year, among discussions of educational policy, we find this statement,—"We may claim it as a distinction, that, in the seats of academic learning, little or nothing useful is taught:" and again,— "Greek is useless; but its uselessness is the very strongest reason for its being a compulsory subject in the University course,—*for the true function of a University is the teaching of useless learning.*" Such expressions are growing less frequent, and the answers to them more direct and emphatic. Indeed it seems hardly worth while longer to reply to them. The existence of the technical schools of the United States, England, Germany and France, their prosperity, the positions of responsibility and trust held by their graduates, the anxiety of schools of the old régime to open courses of instruction in engineering,—these are proofs of the most conclusive kind that instruction in applied science is respectable, that technical education is needed, and that it is supplying a want which the old education was powerless to fill.

But while old school educators have found it expedient to include technical education in their work, they in some cases at least do it in a sort of semi-apologetic way, supplying what a misguided public wants, because the public insists on having it. They call such work "technical training," or "instruction in applied science," and say that it is not education at all. They look on the graduate from such courses as an inferior being, who may perhaps be worthy of some praise because he successfully completed a rigid course of study, covering the usual four years' time, and including work in which equestrian skill is useless; but who is nevertheless to be pitied because of his want of taste in joining the plebeian throng, instead of seeking admission to the aristocratic circles which they represent. This feeling is fortunately growing less pronounced. The mingling of the two classes of teachers in colleges and universities which carry on both kinds of work, and the meeting of the two classes of students in the class room, the debating society and in oratorical contests, are teaching mutual respect. In public discussions, also, the advocates of the old education have by no means had the best of the argument. The address by President Francis A. Walker on "The Place of Schools of Technology in American Education," delivered before the University convocation at Albany last year, contains an unanswerable statement of the claims of the instruction afforded by them to rank as of the highest educational value. After speaking of the success of such schools, as shown in their effect on the industries of the country, he said, "I go far beyond this, and assert for these schools that they have come to form a most important part of the educational system of the country, and that they are to-day doing a work in the intellectual development of the country which is not surpassed, if indeed it be equaled, by that of the classical colleges. I believe that in the schools of applied science and technology as they are carried on to-day in the United States—involving the thorough and most scholarly study of principles directed immediately upon the useful arts — is to be found almost the perfection of education for young men. Too long have we submitted to be considered as furnishing something which is indeed more immediately and practically useful than a so-called liberal education, but which is, after all, less noble and fine.

Too long have the graduates of such schools been spoken of as though they had acquired the arts of livelihood at some sacrifice of mental development, intellectual culture, and grace of life. For me, if I did not believe that the graduates of the institution over which I have the honor to preside were better educated men, in all that the term educated man implies, than the average graduate of the ordinary college, I would not consent to hold my position for another day. It is true that something of form and style may be sacrificed in the earnest, direct, and laborious endeavors of the student of science; but that all the essentials of intellect and character are less happily achieved through such a course of study, let no one connected with such an institution, for a moment concede!"

The position taken in the clear, emphatic and unmistakable sentences quoted, and established in the following part of his address, is made the more striking by the fact that it expresses the conviction of an able educator, whose work has been done at the classic center of the country.

The position of schools of technology is one of usefulness and assured success, in which all who have contributed to it, or who have enjoyed the benefits arising from their work (and who has not?) may take just pride. They have passed triumphantly through the first stage of their existence, the struggle for recognition, and have now reached the period where their usefulness depends on the wisdom of their management, and not on a precarious support. It is not too much to say that if they should content themselves with their present methods of work, and their present resources, they would continue, for many years, to be, as they have been in the past, an invaluable agency for the industrial development of the country, for the intellectual betterment of their students, and for the general elevation of the several engineering professions. But it would be strange indeed if perfection had been found already, either in courses of study, or in methods of instruction, since these have been in existence only a few years, and have been developed under great difficulties. The rapid advance made already is only a promise of what is to come, for the same able men who so happily shaped the earlier and present courses are still at work, and younger men, trained in these courses, and with experience in the engineering professions, are also bending their energies to the same end.

The primary aim of an engineering course is a practical one; namely, to fit the student in the most thorough and perfect manner possible, for success in the practice of his profession. The educational aim is wholly secondary, if it be recognized at all. Engineering courses, as now arranged, and the instruction given under them, are quite practical in their bearing; and the marked success attained by graduates from them, as contrasted with graduates abroad, has been attributed to this feature in official reports there. But the arrangement of these courses has been in part controlled by the necessity of providing a part at least of the instruction given, in classes already created for students in general courses; and also in part by fashion, for unfortunately there are "fads" in education, as in other things. The leading engineering courses at present provided are civil, electrical, mechanical, and mining engineering. They have much that is common, and in many schools, the work for the first, or Freshman year, is the same for all of them. In some, the second year is common also. But in all the schools, there are subjects in each of the three following years which are also in each course, and the students are all put through the same routine, irrespective of its particular fitness to their professional future. This is, in many institutions, an unfortunate necessity at present, because of their inability to provide the teaching force necessary for the formation of distinct classes in each course. In other places, not only are all engineering students put in the same class in certain subjects, but also all students in the classical and scientific courses; and, worst of all, put through work intended for the general course students, with no reference whatever to the needs of the engineers. This may be convenient for the professor, it may keep down the salary list of the trustees, but is it just to the student?

Too many teachers, learned in their special lines of work, enthusiastic, and anxious to lead their students as far as possible into fields so attractive to them, forget that it is not the purpose of these courses to produce scientists. The amount of work to be done by the student in lines bearing directly upon his chosen work is so great that the four years commonly allotted to it is found all too short, and it is therefore necessary, in order to the securing of the best results, that the work set before him in any subject be very carefully selected and limited. The wealth of knowledge embraced in any branch of science is now so great that an adequate presentation of what the professor would consider even an elementary course in it, would require many times the time which may be properly allotted to it. And it is perhaps well that this is true. The danger is that the parts of a subject which are most desirable for the student to know will not be recognized by him, or not made so thoroughly his own as to escape the erasing process which time so ruthlessly applies to his mental tablets. When the time of need comes, he finds himself in possession of a pleasant recollection of certain hours spent in a certain room, listening to able lectures, in the presence of bottles and tubes, pretty pieces of polished brass and hard rubber, pretty colors wonderously changing, sweet sounds and bad smells. He has a faint impression that sometime in the sequence of hours so spent, something was said which might possibly be worth something to him now, if he could only recall it; and, if he kept good notes, or used books of reference, he begins the weary search for something—somewhere.

Happily for his successors on the students' bench, the evil has been recognized, and the remedy is being applied. But there is danger in the other direction also. The process of selection may be so applied and instruction so given, as to present the subject as a series of isolated facts, disjointed, having no necessary connection with or relation to one another;—a sort of omnibus collection of scientific rules of thumb,— the result being only less unhappy than in the first case. It is possible so to collect, classify and connect the chosen topics as to widen their meaning, and increase their practical value to the student, deepen their impression on his memory, making them more certainly available in time of need; and also so to present them as to afford him an outline of the science as a science, increasing their educational value.

The remarks made apply to the scientific and other subjects which are generally considered as a necessary preparation for the strictly technical work which follows. The latter work is, or should be, in the hands of men technically trained, and experienced in the practice of their branches of engineering, and the instruction which they give is naturally guided throughout by the consideration of its practical bearing. The time set apart for the preliminary work, mathematics, physics, chemistry, etc., is so great that it is found impossible to begin the characteristic work of the course as early, or to treat it as fully as is desirable. The work usually done in mathematics is particularly worthy of mention in this respect. A knowledge of analytical mechanics and strength of materials is considered an essential preparation for the last year's work in the four engineering courses named. But to do that work, the student must know the elements of calculus, and that subject needs other preparation, the whole forming a sequence of strictly preparatory subjects, reaching up to the beginning of the Senior year. Nearly one-fourth of the time of the entire course is thus given up to preparatory training in one line of work only. Skill in certain parts of this mathematical work is certainly of great value to the engineer, but is that any reason why he should be compelled to plod or stumble through a mass of matter that has no bearing whatever on any part of his work?

Heretical as the idea is considered, many are beginning to claim that mathematics as now taught is a stumbling block in the way of the engineer. Mathematical texts and courses have received their present form in order that they might afford the broadest possible foundation for the future intricate work of the mathematician, the physicist, and the astronomer. But the demand that the engineer should follow the same course and the same methods is as unreasonable as are the demands of the old classical school. How many engineers ever use higher mathematics in their professional work to-day? I venture to say that not one in a hundred does.

In the practice of any one of the professions named, there is so little occasion for the use of anything more complex than simple arithmetic and algebra, with an occasional sine, cosine or tangent, and logarithms, that the rest is soon forgotten. What percentage, think you, of graduates can, three years after graduation, carry out more than two or three trigonometric transformations, or recall half a dozen integration formulæ, or use Taylor's theorem, without hunting up text books? If the test could be applied, the percentage would be found very small. Continual practice is necessary, as in other things, if one would be ready in the use of higher mathematics, and the fact that successful engineers, who showed considerable mathematical ability in college, confess to the loss of the greater part of it, of itself shows how little real need of such skill there is in the practice of engineering. But we may go farther. The engineer should be so trained as to fit him, not only for the successful practice of his profession, as it is when he enters upon it, but also so as to fit him to improve upon the work of his predecessors in it, to introduce better methods, if such are possible, and to advance its science and art as far as his ability will allow. To what extent will skill in higher mathematics be an essential in this regard? The question can best be answered by the consideration of past experience. Take the case of electrical engineering, since it is a new and broad field, affording abundant opportunity for mathematical discussion, and to which the best mathematical skill the world has produced has been applied. A great store of valuable matter has been added to the science of physics as a result, but we search almost in vain for a single thing in the practice of the profession which is due to mathematical analysis of the higher order. In continuous current work, Ohm's law, the experimentally determined facts of induction, of electro magnetism, and of the properties and behavior of conductors, economic considerations requiring the use of nothing but arithmetic or algebra in their application, cover the entire ground of plant design, construction, testing, and operation. The peculiar field for mathematical skill is considered to be that of alternating current work. But here a close examination of facts leads to the same result. The alternating dynamo and the converter are what they are to-day because of the experimental work done on them in the laboratories of the factories and colleges of the United States. Most excellent mathematical discussions of such machines have been printed, but they complacently persist in doing what the discussions say they ought not, and in refusing to do what they ought. In the matter of measurement even, the methods given us by analysis are available only under conditions rarely attainable, and in some work (the determination of converter efficiencies for example), they cannot be depended on at all.

With these undoubted facts in view there are only two reasons for the study of higher mathematics by engineering students; first, as a mental discipline, and second, because certain parts of such mathematics are helpful to him, in enabling him the more easily and clearly to perceive the truth of certain facts and principles in physics and mechanics. That the mental discipline so acquired is valuable, no one can well deny. If this discipline could be acquired in no other way, we should have one good argument for retaining all the mathematical work now required of the student. But this is not true; for the methods of discussion which must be followed in the scientific and technical parts of the courses are the same as those used in mathematical work, and the student will suffer no loss in mental discipline through the suggested diversion of a part of his time from the more abstruse parts of the mathematical subjects as now carried on.

It seems clear that the best reason that can be assigned for mathematical training in engineering courses is that the use of mathematical processes is essential to the mastery of the scientific principles underlying engineering practice. There are few problems arising in such practice which cannot be solved by simple arithmetic or algebraic processes. If to these we add graphic methods, not requiring analytical skill, we have all that is necessary for the handling of quite difficult questions. The rule of three even is a very satisfactory tool in the hands of one who knows how to use it, and a large part of physics at least can be taught to one having nothing but the rule of three on which to depend. There are many successful engineers to-day who had nothing better to start with, and who find such simple processes as those named, together with the current engineering pocket books, sufficient for their ordinary practice. If such an engineer has cases to deal with which have become common, he can rely upon past practice, and use his pocket book of rules, tables, and formulæ. But it is the unusual case, involving new conditions, presenting difficulties not before encountered, that call for the true engineer. The man who successfully meets such cases must be able to see clearly the case before him, to recognize its peculiarities and difficulties, to see the bearing of the scientific principles involved, and thus to work out a new and correct solution. It is in the ability to do this that the superiority of the well trained engineer over the "practical man," or pocket book engineer consists. While, as stated, much scientific truth may be taught to one with little mathematical training, the knowledge that one so taught obtains, is certainly of a different order from that obtained by one with mathematical power. The truths of mechanics and physics are broad and far-reaching, and it is absolutely impossible to express them fully or to show their bearing and relations without the use of more or less advanced mathematical methods. The thorough comprehension of them is therefore possible only to the student who has mastered such methods.

Here, then, lies the claim of mathematics to a place in engineering courses of study. But while certain parts of the branches of pure mathematics now in vogue are essential to the proper training of engineers, it by no means follows that all the work prescribed in such subjects is valuable or beneficial to the student. A considerable part of the more advanced topics in algebra, trigonometry, and analytical geometry have no place whatever in the discussion of applied science, and do not fall in the category of essentials. A carefully selected course in mathematics for engineering students is much needed, and if we could have such a course arranged by a number of men well trained in engineering science, with the aid of a mathematician or two in sympathy with engineering work, the adoption of such course would speedily follow, and result in marked improvement in the work of technical students. In selecting the material for such a course, the purpose should be to provide for the student's training in all methods which may possibly be needed by him in his scientific or technical subjects, putting a liberal interpretation on this view. I believe it is possible to arrange such a course, in such a way that the time required to cover it, as pure mathematics, from trigonometry through calculus, need not exceed one year. The examples and problems necessary for illustrating the mathematical processes, and giving the student facility in their use, should be drawn from appropriate topics in mechanics and physics, and if possible from the student's own work in the laboratory. A part of the time saved by this modified course should be spent in more extended problem solution of various kinds, in drill in methods of computation, and in the checking and proving of results, until the student no longer uses long division when he wants to divide by two, loses his innate fondness for seven place tables, and always stops his calculations short of the seventeenth decimal place. Such a modification will remove one of the greatest difficulties encountered by the average student, will make the work more attractive and more useful, because it is applied in ways whose bearing and importance he can see, instead of to a collection of puzzles, which, when solved, keep him forever guessing why they were set before him.

I have spoken thus fully of the mathematics of engineering courses, not because that is the only subject which needs revision, nor because it needs revision more than anything else, but because it is the subject in which greatest opposition to change will be found. It is probable that I shall be charged with proposing to lower the standard of engineering work, by those who consider the standard of such courses as gauged by the amount of higher abstract mathematics contained in them. That was the charge made by old schoolmen when it was proposed to modify and modernize the Arts course in our colleges. We have seen extensive changes made, and more radical ones have been seriously considered, but the Arts course survives, and graduates from it are found no less learned and able than those who preceded them. I feel sure that a revision of engineering courses, in mathematics and in other subjects as well, on the lines indicated, will be found to result, not in a lowered standard, either technically or with respect to educational value, but in a marked improvement in all respects.

That a change from the orthodox routine of mathematical study is both possible and beneficial has been demonstrated by Professor Perry at the Finsbury Technical College of London. He has had the good fortune to work in a peculiar field, an institution wholly unlike anything else in England, and therefore free from educational fashions and traditions. But for this, he would probably have found what he has done, impossible in England. The results secured by him have attracted considerable attention abroad and should encourage others to make a similar attempt here.

Revision of the same sort is needed in other subjects. The courses in general physics and chemistry, as now given, are better suited to the needs of the engineer than those given ten years ago, but there are still many topics presented which might be omitted with advantage. Why should all students be taken through a long discussion of the theory of surface tension? What need has the mining engineer for the theorems of electrostatic potential, or the civil engineer for a comprehension of the phenomena of high vacua? Why should the mechanical engineer be troubled with the chemistry of storage batteries and why should the electrical engineer know the chemistry involved in words beginning with *di*—and ending two lines away with *ine*? Other subjects might be mentioned, but what has been said is sufficient to point out existing defects, and to indicate the policy which should direct the needed revision.

Literary subjects have generally been looked upon as valuable because of the polish they are supposed to impart, and their presence in engineering courses has often been allowed rather than desired by technical instructors. This is a mistake. The success of an engineer does not depend alone on his professional attainments. He may build a bridge, the building of which requires of him the exercise of the highest engineering talent. The bridge may be a perfect success, and he may be well paid for his work, but if he stop at that point, his work is not as successful as it should be. If he is also able to write a paper embodying what is new in the work, read it before his engineering society, take a creditable part in its discussion, the whole being done in neat and attractive language, his usefulness to his profession, to the world, and to himself is thereby increased, and opportunities for other and more difficult work are more likely to come to him than if he had not the ability to write and talk, as well as to build. The student should have literary work placed before him, and the practical value of that work should be pointed out and insisted on as in other subjects. He should study the principles of rhetoric and composition, and apply them in practice on assigned topics, in which scientific and technical subjects should predominate. He should read much, in well-chosen scientific, technical and literary lines, to increase his vocabulary, make him familiar with examples of good literary style, and help him in the formation of habits of correct and easy expression. He should take an active part in debating societies. And he should also have practice in the writing and discussion of technical papers, in the student engineering society. The study of German or French may well occupy a part of his time, though I should consider it more important that he should be thoroughly at home in the use of English. I am inclined to think that ethics might be made a practical subject in the engineering courses. What an opportunity there is for the application of practical ethics to wire joints and plumbers' bills. Would that the student might leave his college so thoroughly imbued with correct principles that he could never after tolerate defective or dishonest work of any sort whatever.

The larger proportion of the schools which give engineering instruction in this country are the state universities, which owe their existence to the efforts of that great statesman, Justin S. Morrill. Receiving their support, as they do, from the national and state treasuries, they at least owe it to the nation that the students they send out should be fitted for good citizenship. They are trained to serve their country in time of war, but it is even more important that their training should enable them to exert their influence for the promotion of the general well being in time of peace. Grave questions confront us as a nation, and every student, in every course, in every college in the land, should be given instruction which will enable him to form sound opinions, and to use his influence effectively. A thorough knowledge of our own institutions and history, and of the general principles of political and social science, are essential to good citizenship, and the nation must look to the schools and colleges, as its most powerful allies in combating the errors of ignorance and vice.

The suggestions thus far made refer to that part of the work of technical schools which is in the control of their faculties. The courses of study are framed by them, and the work of the class rooms is shaped by the professors individually. But the future of these schools depends also upon the trustees who govern them, and upon the public which furnishes them with means to use. The ideal technical school would have its courses of study arranged each with reference to the needs and future interests of the students following it, and as independent of other courses as if they were not in existence. The subdivision of classes would be made so great as to insure like independence of work, and also to insure the teacher's personal knowledge of the daily work of each student. The teachers chosen, particularly those in charge of the characteristic work of each course would be men well trained and with large experience in the practice of their respective branches, and whose vacations at least are spent in such practice. In this way alone can the fruits of ripe experience, and the best methods of recent practice be made available to the student.

In laboratories, space and apparatus should be provided, which will enable each student to do his work without being embarrassed or hindered by the work of fellow students. In the advanced laboratory work, it is especially important that the machinery provided be the best of its class, and of commercial size. It is as ridiculous to attempt to train an electrical engineer with dynamos no larger than one's hat, as it would be to train a jockey on a Shetland pony. The young graduate has at best much to learn when he leaves college, and he ought in college to be made as familiar as possible with the handling of machinery and apparatus such as he will have to handle on leaving. The time spent in college is the time for learning the rudiments, for blunders and mistakes, and for learning how to get out of difficulties. The student who has and uses such opportunities, acquires a confidence in himself which can be obtained in no other way, and saves himself also the mortification and loss of prestige which invariably follow blunders made later.

Such faculties, such laboratories, and such equipments are expensive, but I believe that the material advancement of the country which would follow expenditures so made would prove a handsome return on the investment.

It would be well if we were each able to follow the policy adopted by Stevens Institute under the wise leadership of President Morton, and confine our attention to, and expend our means in some one branch of engineering, one state institution taking say civil engineering, the neighboring state taking mechanical engineering and so on, for it is better to do some one thing in the most perfect manner possible, than to attempt many things and secure only moderate excellence in any. But state pride makes this impossible, if there were no obligation expressed or implied in the terms of the Morrill act, to provide in each institution founded on it, instruction needed "in the several pursuits and professions of life." We must be content to see only slow progress made in directions requiring more money, for boards of trustees and the public also are accustomed to consider the views of professors as more or less "cranky," and professors as enthusiasts who need restraining rather than encouragement. But with reason on our side, and with the splendid examples set before us in Germany, we may expect to rouse public interest and win public support in time, and to become the world's leaders in technical education, as we of right ought to be.

# PAPERS READ.

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PERSISTENCE OF VISION. By Prof. ERVIN S. FERRY, Cornell University, Ithaca, N. Y.

[ABSTRACT.]

THE object of this series of experiments was primarily to test the validity of the hypothesis advanced by Plateau and Nichols that the duration of retinal impression depends upon the color of the light entering the eye, and secondarily to determine the principal factors producing persistence of vision and the laws connecting them.

The duration of retinal impression was measured for various wave lengths throughout the entire visible normal spectrum and the values thus obtained platted in curves showing relation between wave length and duration of retinal impression.

Fig. 1 is for the case of the normal eye, in which the separate curves are for spectra of different luminous intensity varying from one to twenty-four. Fig. 2 shows the distribution of luminosity, as seen by the normal eye, of the incandescent lamp that was used as a source of light. Fig. 3 gives the values of retinal persistence for the spectrum as seen by a red-blind person. Fig. 4 is the corresponding case for various green-blind observers.

From the data derived from these experiments is deduced the following

SUMMARY OF RESULTS.

I. The duration of retinal impression is very different for different regions of the spectrum, being at a minimum value at the region of maximum luminosity and gradually increasing to maximum values at the ends of the spectrum.

II. If the luminosity of any region in the spectrum be so changed that the values vary in geometrical ratio, the corresponding values of duration of impression will approximately vary inversely in arithmetical ratio for regions of ordinary brightness.

III. Color has, at most, very slight influence upon retinal persistence. Luminosity, including the brightness of the light and the retinal sensitiveness, is the all-important factor.

IV. For ordinary values the following empirical law is approximately true: *Retinal persistence varies inversely as the logarithm of the luminosity.* Or,

$$D = \frac{1}{n \cdot log. L}.$$

V. The values of retinal persistence in dichroic eyes are very different than in normal eyes. For instance, light impressions of red last much longer on the retina of red-blind persons than on the normal, yellow somewhat longer than normal and the other colors about the same as normal. With green-blind persons, green impressions persist much longer than normal, red a little less than normal and the other colors the same as normal.

VI. The very marked departure from the normal values of retinal persistence in dichroic eyes for the region of their lacking color sensation, affords a precise and convenient method of determining color blindness.

VII. Within the range of these experiments, it seems probable to a high degree, that age increases the values of retinal persistence to a nearly equal amount in all regions of the spectrum.

[This paper is printed in full in the American Journal of Science for Sept., 1892.]

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E. M. F. BETWEEN NORMAL AND STRAINED METALS IN VOLTAIC CELLS. By Prof. W. S. FRANKLIN, Ames, Iowa.

[ABSTRACT.]

THOMSON'S law of dependence of E. M. F. of galvanic cell upon energy of reaction leads one to expect a strained metal to act as zinc towards normal metal of same kind — whether strain is *compression* or *elongation*.

Stretched copper is as "zinc" towards normal Cu.

Compressed copper is as "Cu" towards normal copper.

Stretched silver is as "copper" towards normal silver.

Hence Thomson's law is not applicable to energy of elastic deformation when a strained metal is used as one electrode of a battery.

Thomson's law should be modified as follows: The E. M. F. of a voltaic cell depends upon the energy of REVERSIBLE actions which take place in a cell, *e. g.*, the dissolution of a strained metal is *irreversible* and the energy associated with the *irreversible* part of the reaction seems to be without influence upon the E. M. F.

[This paper will be printed in American Journal of Science.]

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NOTE ON THE PHOTOGRAPHY OF THE MANOMETRIC FLAME, AND THE ANALYSIS OF VOWEL SOUNDS. By Prof. ERNEST MERRITT, Ithaca, N. Y.

[ABSTRACT.]

THE work to be described was undertaken with the object in view of checking the results of Helmholtz and König on the analysis of the principal vowels, and of continuing the analysis to other vocal sounds. The manometric flame has been used for this purpose, and in order to obtain permanent records a modified form of burner has been constructed which gives a flame sufficiently brilliant to allow it to be photographed. The

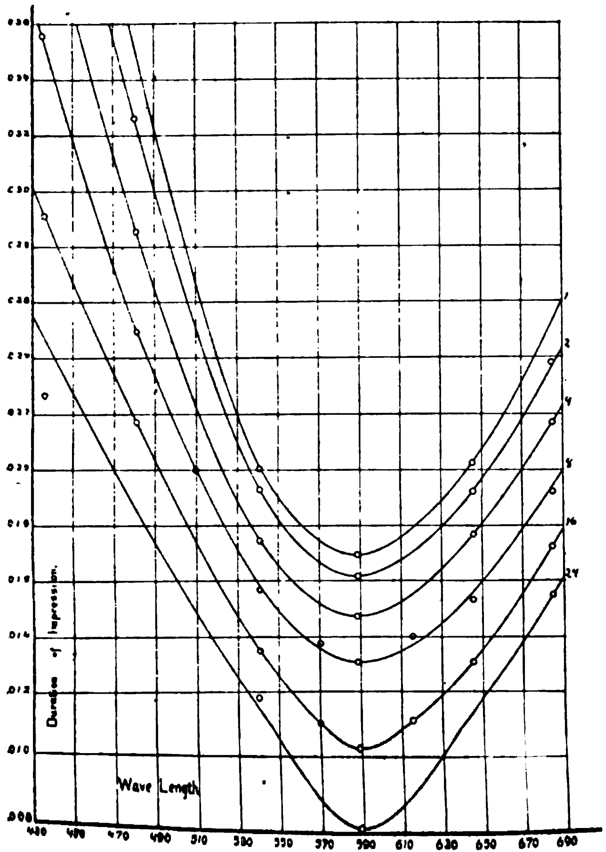


FIG. 1. Duration of Impression of Normal Eye for different colors and different intensities.

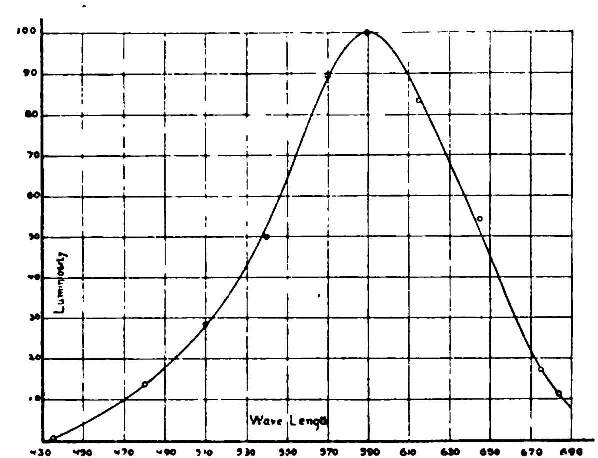


FIG. 2. Distribution of Luminosity in 16-candle power, 100-volt Edison Incandescent Lamp.

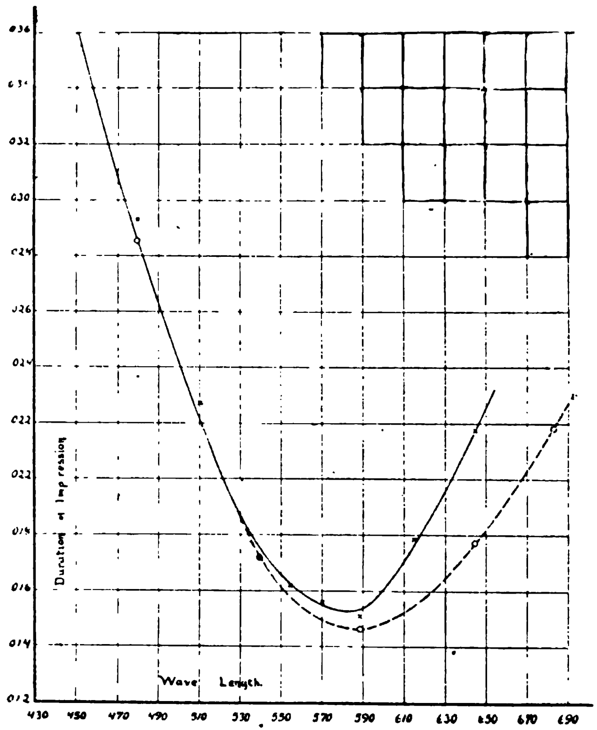


FIG. 3. Duration of Impression for different colors of Red-blind Eye.

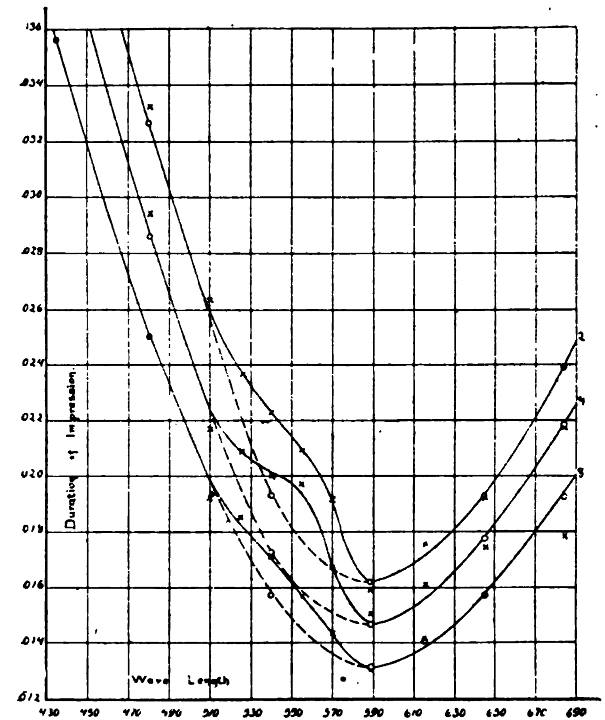


FIG. 4. Duration of Impression of Green-blind Eye.

burner is practically the same as an oxhydrogen blast lamp, gas being used in the central tube and oxygen on the outside. The flame obtained is quite sensitive when connected with a manometric capsule, and is of high actinic power. Photographs are obtained by throwing the image of the flame upon a rapidly moving plate.

The results so far obtained consist of preliminary analyses of all of the vowel sounds, and a rather complete study of the vowel A as in father. About fifty negatives have been taken of the flames produced by this vowel as sung by different voices and at different pitches. With male voices of the ordinary pitch I obtain a characteristic overtone of practically the same pitch as that given by König; but in the case of voices that are naturally high the overtone seems to be also of a somewhat higher frequency.

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THE DISTRIBUTION OF ENERGY IN THE SPECTRUM OF THE GLOW-LAMP. By Prof. EDWARD L. NICHOLS, Cornell University, Ithaca, N. Y.

[ABSTRACT.]

THE apparatus used in this investigation consisted of a galvanometer of high sensitiveness, a linear thermopile of ten Sb–Bi junctions and a spectrometer. Upon the table of the last named, was placed a bisulphide of carbon prism with thin glass faces. For the eyepiece of the observing telescope, the thermopile could be substituted, the adjustment being such that its face would correspond with the position of the cross hair. The prism was calibrated in the visible spectrum, by means of the Fraunhofer lines. A Cauchy formula was obtained by means of which wave lengths in the infra red to 3.0$\mu$ could be determined accurately. (Rubens has recently shown that bisulphide of carbon follows the Cauchy formula with great exactitude throughout the spectrum.)

Three lamps were tested. (1) An Edison lamp, untreated filament of black but shining surface. (2) A lamp with an especially prepared filament the surface of which was of lamp black. (3) A filament precisely similar to (2) viz., of nearly circular cross-section, but built up by treatment in hydrocarbons so as to present a silver gray surface.

The results obtained cover a range from .5$\mu$ to 3.0$\mu$ with energy expended in the lamps, between 1-5 watts and 85 watts. It is found that the energy curves for black and gray carbon are distinct, the Edison curve being of the former class. The position of the maximum and its change with the degree of incandescence is also brought out graphically by means of the curves.

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THE ABSORPTION SPECTRA OF CERTAIN SUBSTANCES IN THE INFRA-RED. By ERNEST F. NICHOLS, Cornell University, Ithaca, N. Y.

[ABSTRACT.]

THE apparatus used in this investigation was an ordinary spectrometer in which the filament of an incandescent lamp was used instead of a slit.

The substances were interposed between the lamp filament and the collimating lens of the spectrometer. Dispersion was produced by a carbon bisulphide prism calibrated for Fraunhofer lines in the visible spectrum and the Cauchy constants computed for the infra-red calibration. The energy was measured by a linear thermopile in circuit with a galvanometer. The thermopile was interchangeable with the spider line in the eyepiece of the spectrometer.

The substances investigated were: water, potassium alum, ammonium iron sulphate, a weak solution of oxyhæmoglobin, absolute alcohol, chlorophyll in alcohol, plate glass, hard rubber, cobalt glass.

The results are shown by curves platted in two different ways: one way showing the relation of percentage of transmission to wave length, and the other platted to show the relation between wave length and percentage of transmission using the ordinates of the energy curve of the source everywhere as unity so that the ratio of the area of the curve thus platted for each substance to the area of the energy curve of the lamp should give the percentage of total transmission.

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## FURTHER EXPERIMENTS ON THE SPECIFIC INDUCTIVE CAPACITY OF ELECTROLYTES. By Prof. EDWARD B. ROSA, Middletown, Conn.

[ABSTRACT.]

IN a paper read before the American Association for the Advancement of Science at Indianapolis, I showed why electrolytes may be considered to have a genuine specific inductive capacity, nothwithstanding the fact that they are conductors of electricity. The subject has been studied anew and further experimental evidence adduced for this conclusion.

It is well known that a dielectric in a variable electrical field tends to move into regions where the electric force is greater or less according as the specific inductive capacity of the body is greater or less than that of the medium. For example, glass and sulphur in air move toward the regions where the force is greater. In water and alcohol it moves much more strongly in *the opposite direction*. Carbon moves toward region of stronger electric force, and exerts greater force in so doing in media of larger values of K. In alcohol the force exerted is twenty-five or thirty times greater than in air, and in water fully seventy times greater force than in air. This is a measure of the specific inductive capacity of water, and agrees very well with results found before by a different method. The same method gives the specific inductive capacity of ether, petroleum oils and other liquids having a smaller value of K.

In the paper the mathematical theory of the problem is given, the field consisting of lines of force and equipotential surfaces which are circles, intersecting orthogonally, being due to two oppositely charged parallel wires. The dielectric or conductor in question is suspended by a torsion balánce in the neighborhood of these electrodes, and the force exerted upon it is measured.

The conclusions by this independent method verify those announced two years ago.

[This paper will be printed in London Philosophical Magazine.]

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## On the dispersion of radiations of great wave length in rock salt, silvite and fluorspar. By Heinrich Rubens and Prof. Benj. W. Snow, Bloomington, Ind.

[ABSTRACT.]

The thin and perfectly uniform layer of air, enclosed between a plate of fluorspar and a plate of glass, served as a reflector for the radiations from the zirconia lamp of Linnemann. The two resulting beams of light, one reflected from the front and one from the rear surface of this air film, were capable of producing mutual interference, and caused, when concentrated upon the slit of a spectroscope, the otherwise continuous spectrum to be crossed by a series of vertical interference bands. The wave length $\lambda$ of each dark band, multiplied by a certain whole number, is always equal to the product of twice the thickness $d$ of the layer of air and the cosine of the angle of incidence $a$ of the rays as they fall upon the diathermous fluorspar plate. Within the limits of the visible spectrum the wave lengths of these dark bands can be determined by means of a calibration with the Fraunhofer lines, and from this data the order $m$ of the interference band and the constant $k = 2\,d\cos a$ may be calculated. The knowledge of these two constants is sufficient to fix the wave lengths of the interference bands in the infra-red, the positions of which were determined with the aid of the linear bolometer. In this way for a series of angular deviations the corresponding wave lengths were measured, that is, a number of points were located in the $\lambda - \varphi$ plane and the smooth curve joining them gave the required curve of dispersion for the substances under investigation.

Prisms were cut from the three substances, rock salt, the corresponding crystallized potassium chloride, and fluorspar, and the character of the spectrum produced by each mineral was studied in the manner just described. In each case it was found possible to reach a wave length a little greater than $8\mu$, beyond which point the energy became too feeble to be measured. Especially is it of interest to compare our curve of dispersion for a rock salt prism with the calibration of this material made by Professor Langley. As is well known his observations from about $2\,\mu$ to $\lambda = 5.3\,\mu$ fell almost exactly upon a straight line, and as a calibration beyond this point was impossible, his values for greater wave lengths were assumed to be given by exterpolation, according to this same law. Our own measurements gave a curve of very nearly the same character between $\lambda = 2\mu$ and $\lambda = 5\mu$. Here, however, the inclination of the curve to the horizontal axis of wave lengths begins gradually to lessen, and at $\lambda = 8\mu$ the effect of this curvature is so considerable that a straight line

exterpolation from $\lambda = 5\mu$ on would introduce an error amounting at least to $1\mu$. It is, therefore, beyond a doubt that Langley's wave lengths between $\lambda = 5\mu$ and $\lambda = 8\mu$ are considerably greater than he assumed them to be.

The dispersion in crystallized KCl, silvite, in the visible spectrum is hardly less than that in rock salt, but decreases rapidly in the infra-red, and at $\lambda = 8\mu$ has a value only about one-third that in rock salt, so that this material, notwithstanding its many good qualities, is but poorly adapted to the measurement of very long wave lengths.

The direct reverse is true of fluorspar. The dispersion in this material in the visible spectrum is exceedingly small, and continues to decrease as far as $\lambda = 2\mu$; but at this point the curvature of the curve changes, the dispersion increases as the wave lengths become longer, and at $\lambda = 8\mu$ reaches a value but little inferior to that in the red.

As compared with rock salt and silvite, the dispersion in fluorspar in the visible spectrum is very small, but in the infra-red is many times greater than in these latter materials, so that this substance is well adapted to produce prismatic heat spectra, a property whose value is increased by the convenience with which it can be worked as well as its durability in the air.

[This paper will be printed in Wiedemann's Annalen.]

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ON THE DISTRIBUTION OF ENERGY IN THE SPECTRUM OF THE ARC. By Prof. BENJ. W. SNOW, Bloomington, Ind.

[ABSTRACT.]

BY means of a lens, enlarged images of the electric arc and of the carbon points of the electric lamp were projected upon a screen placed immediately before the slit of a spectrometer. A small rectangular opening in this screen allowed the slit to be illuminated only by the light coming from the central portion of the spherical arc, the light from the carbons and from those portions of the arc nearest the carbons being intercepted by the screen. The cross hair in the eye piece of the instrument was replaced by the sensitive filament of a linear bolometer, which afforded a means of investigating the distribution of energy in the spectrum of the arc itself without the superposed spectrum of the incandescent carbons. A flint glass prism of high dispersion was used to analyze the light, and was calibrated according to the method described in the preceding paper. The energy curve, plotted with galvanometer deflections as ordinates and wave lengths as abscissæ, gave the distribution of heat in the various portions of the spectrum of the arc. This curve has two maxima lying in the region of the H lines, and five weaker maxima beyond the red, the visible spectrum being noticeably deficient in thermal radiation.

One of the interesting points shown by this curve is the fact that the maximum of the energy in the arc, as indicated by the bolometer, lies be-

yond the H lines so far in the ultra violet as to exert only a feeble effect upon the eye, while the optically brighter band in the violet represents a smaller expenditure of energy.

[This paper will be printed in Wiedemann's Annalen.]

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ON THE INFRA-RED SPECTRA OF THE ALKALIES. By Prof. BENJ. W. SNOW, Bloomington, Ind.

[ABSTRACT.]

To investigate the spectra of the metals, the appåratus described in the previous paper was used with the single modification that the carbons $8^{mm}$ in diameter were bored out, and the cavities $3^{mm}$ in the positive electrode and $1\frac{1}{2}^{mm}$ in the negative were filled with the chloride of the metal to be studied. The heated carbon points caused the salt in question to boil and to send a constant and uniform stream of metallic vapor directly into the arc, so that the latter lost its usual violet color and assumed the characteristic color of the salt under investigation. The bolometer filament was then moved through the spectrum, and the distribution of energy measured as before. These results, when plotted, gave curves wholly different in character from that of the electric light, for the characteristic band spectrum of the arc had disappeared entirely and was replaced by the truly line spectrum of the metals. In this way the visible and infra-red spectra of the five alkalies were explored and their intensities measured. The results obtained were then compared with the values calculated with the aid of the formulæ of Kayser and Runge, and in many instances close coincidences were observed; in other cases, however, wide discrepancies occur, so that these measurements can hardly be looked upon as a verification of Kayser and Runge's formulæ.

[This paper will be printed in Wiedemann's Annalen.]

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AN EXPERIMENTAL COMPARISON OF FORMULÆ FOR TOTAL RADIATION BETWEEN 15° C. AND 110° C. By W. LECONTE STEVENS, Rensselaer Polytechnic Institute, Troy, N. Y.

[ABSTRACT.]

THE principal object of this investigation was to compare two formulæ, one by Professor Stefan, of Vienna, the other by Prof. H. F. Weber, of Zürich. Two other formulæ were also taken into account, one by Dulong and Petit, the other by Rosetti.

An account is given of the method of work adopted, and the formula obtained, by Dulong and Petit. The same is done for Rosetti, Stefan and Weber.

A description is given of the apparatus employed in the present work and the precautions applied to secure accuracy. From the large number

of tables of measurement, selections are given, and these tables are discussed. Curves are given, showing the relative accuracy of Stefan's and Weber's formulæ between 15° and 110° C. as tested by experiment, and finally curves are given, computed from each of the four formulæ, from 0° to 800° C.

Incidentally at the close a comparison of the emissive powers of iron and copper is afforded from the experiments already cited.

[This paper will be printed in the American Journal of Science.]

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ON THE CONSTANCY OF VOLUME OF IRON IN STRONG MAGNETIC FIELDS. By Prof. FRANK P. WHITMAN, Adelbert College, Cleveland, O.

[ABSTRACT.]

REPETITION of an experiment of Joule, who determined that the volume of iron when magnetized remained invariable, though the length increased.

It has since been shown by Bidwell and others that on increasing the strength of the magnetic field, iron reaches a maximum in length, then decreases below its length when unmagnetized, seeming to tend toward a minimum. It seemed worth while to examine afresh the question of the change of volume under strong magnetization. The apparatus was similar to that used by Joule. The magnetic field was carried up to about 750 c. g. s. units, at which quantity iron, according to Bidwell's results, has nearly reached a constant minimum length.

The delicacy of the apparatus was such that a change of volume of 1 : 30,000,000 could be detected.

The experiments show that Joule's results hold good for stronger fields also, and that there is no notable change of volume in iron up to the magnetization noted above.

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SOME DIFFICULTIES IN THE LESAGE-THOMSON GRAVITATION-THEORY. By Prof. J. E. OLIVER, Ithaca, N. Y.

[ABSTRACT.]

THIS paper is merely supplementary to Maxwell's statement and criticism of the theory, *Enc. Brit.*, art. *Atom*.

Lesage's corpuscles make up what, for brevity, we will call "the gas," though we may find that thermally it behaves less like known gases than has been claimed. Denoting hydrogen at standard pressure and temperature by H, let us write $\rho$, $m$, $v$, $l$, $d$, for the density of the gas and for the mass, velocity, length of mean path, and so-called "diameter" of a mean corpuscle,—the corresponding quantities for H being taken as units. This, for our rough work; for the velocities, etc., would not be uniform. Let $k$ be the average loss, per unit, of momentum in the initial direction

of flight, for corpuscles striking the earth vertically. Take $k = .001$ which is large enough to displace Jupiter about 10″ at quadratures; and $l =, 4 \times 10^{19}$, which brings the free path within Neptune's distance. (This $k$ is too large, and $l$ far too small, unless we concede a greater failure of Newton's law for solar masses and interstellar distances.) Take the sun's disk as covering $\frac{1}{90000}$ of the celestial hemisphere, his $g$ as 28 times the terrestrial $g$, and his attraction for the earth as equivalent to 28000 atmospheres' pressure on the earth's central plane section: then, since the sun's and earth's volumes are each $\frac{2}{3}$ of a circumscribed cylinder, and since corpuscles coming from the sun have for our purpose twice the average effectiveness as due to direction, while for this comparison the $k$ of air pressing against its containing vessel may be called 2,

$$\therefore (.001)^2 \times 28 \times (\tfrac{2}{3})^2 \times \tfrac{2}{90000} \times \rho v^2 \div 2 = 28000,$$

$$\therefore \rho v^2 = 2 \times 10^{14} = 2 \times 10^8 \times k^{-2},$$

*i. e.*, the gas-pressure throughout space would be $2 \times 10^{14}$ atmospheres.

Should the force between atom and corpuscle increase, with diminishing distance, even as rapidly as intermolecular forces appear to do, then the swiftest corpuscles would shoot through the earth with least loss of directed momentum; thus diminishing or reversing the Lesage effect, and not only requiring $\rho v^2$ to be still larger but probably making gravitation a complex function of the masses and sometimes repulsive. This difficulty appears very serious, unless we adopt the vortex-atom theory; but, waiving it, let $\rho = 1$ for instance: then though the gas within the sphere of Neptune's orbit has about sixteen million times the sun's mass, and the gas within our own star-cluster has over $10^{18}$ times the visible cluster's probable mass, yet the velocity $v$ is 100 times that of light, and the flight-energy lost in $\frac{1}{2000}$ of a second by the gas within the earth while traversing a diameter would suffice to heat up the earth's weight of hydrogen almost $2\, k \rho v^2 \times 273° \div$ earth's density, or over $10^9$ degrees.

Maxwell considers this rapid loss to be almost fatal. It demands an immense heat-capacity in every corpuscle to carry off the heat of encounter; whereas the corpuscle's minuteness, and its great quasi-density $md^{-3}$, would rather suggest simple structure and small capacity. In fact, since $l \rho d^2 = m$, $\therefore md^{-3} = l^{\frac{3}{2}} \rho \cdot \sqrt{\frac{\rho v^2}{mv^2}}$ wherein $mv^2$ should not very greatly differ from the ratio which the average heavenly body's absolute temperature bears to that of 0° C.; $\therefore$ probably $md^{-3} > 10^{28} \rho$.

Again, by the kinetic theory, $mv^2$ for the gas should be less than for some astronomical bodies if greater than for others:—hence for some bodies $k$ would be negative and gravity repellent; and in general, gravity would depend upon temperature as well as upon mass and distance.

Finally, we cannot identify the gas with luminiferous ether: for its free paths immensely exceed the wave-lengths, and its corpuscles fly with many times the wave-velocities.

Thus in various ways the hypothesis appears not to accord with what we know of Nature.

A MECHANICAL MODEL OF ELECTROMAGNETIC RELATIONS. By Prof. A. E. DOLBEAR, Tufts College, College Hill, Mass.

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ON THE MECHANICS OF THE THREE STATES OF AGGREGATION. By Dr. GUSTAVUS HINRICHS, St. Louis, Mo.

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THE OCULAR SPECTRUM. By GEO. W. HOLLEY, Ithaca, N. Y.

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ON THE SENSITIVENESS OF PHOTOGRAPHIC PLATES. By Prof. G. W. HOUGH, Evanston, Ill.

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INFLUENCE OF THE MOON ON THE RAINFALL. By Prof. MANSFIELD MERRIMAN, South Bethlehem, Pa.

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DESCRIPTION OF A CONTRIVANCE FOR THE STUDY OF COLOR PERCEPTION AT DEFINITE DISTANCES. By CHARLES E. OLIVER, M.D., Philadelphia, Pa.

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A PHOTOGRAPHIC METHOD OF MAPPING THE MAGNETIC FIELD. By Prof. C. B. THWING, N. W. University, Evanston, Ill.

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ON THE MECHANICAL AND PHYSICAL MEANS OF AËRIAL TRANSIT WITHOUT A PROPELLER. By Prof. DAVID P. TODD, Amherst, Mass. [To be published in the L. E. & D. Philosoph. Mag.]

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NOTE ON THE MAGNETIC DISTURBANCES CAUSED BY ELECTRIC RAILWAYS. By Prof. FRANK P. WHITMAN, Adelbert College, Cleveland, Ohio.

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## ADDRESS

BY

# ALFRED SPRINGER,

VICE-PRESIDENT, SECTION C.

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## *THE MICRO-ORGANISMS OF THE SOIL.*

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THE high office with which you have honored me entails the delivery of an address, which I keenly feel I cannot give in keeping with the standard set by my distinguished predecessors.

Fermentation, though observed since prehistoric times, is perhaps less understood than any process with which chemistry has to deal. The exciters of fermentation are rendered exceedingly difficult of investigation, because they, like all living things, are subject to physiological, or more especially, pathological functions of life; they are so sensitive that any abnormal influence either changes their whole mode of existence, or destroys it altogether; a medium suitable to the life of one special kind is changed by it into products which cease to sustain it, but can nourish a lower class of organisms, whereby concomitant fermentations arise, whose united effects are frequently such as to modify completely those produced by each separately; and for this reason have the specific actions of some ferments either totally escaped observation or been misconstrued. Every succeeding year brings additional proof of the important role played by these minute organisms; and to such an extent, especially has this been the case in connection with the rendition of available nitrogen, that there are good reasons to believe that a clearer comprehension of the actions of the soil ferments will dissipate all the anxiety chemists now entertain as to a gradual diminution of this so essential nutrient.

To Hellriegel, Wilfarth, Wollny, Engelmann, Winograwdski, Warrington and Heräus, can be attributed the most noteworthy experiments in this special line. In order to appreciate the importance of their discoveries, I will, with your kind indulgence, first give a brief historical résumé of the study of fermentation.

Owing to the extreme age of the use of alcoholic beverages, ferments entering into their production are best known; and this, added to the fact of their being larger and thus permitting of better examination, has been the determining cause of basing investigations and deductions upon their behavior.

That the art of cultivating the vine and making wine is attributed by the Egyptians to Osiris, by the Greeks to Bacchus, by the Israelites to Noah, and the brewing of beer to Gambrinus, shows how old these discoveries must have been. The effects of fermentation are sufficiently striking to have called the attention of primitive man to them. The ancient tribes of Asia and Africa understood how to ferment not only grape juice, but also to obtain alcoholic beverages from substances like starch, not directly fermentable. They used soured dough or beer-yeast as leaven for their bread and knew how to prepare vinegar. The alchemists were wont to clothe their thoughts in such words as to make it difficult for us to decide what precise ideas they attached to the expressions of "Fermentation and Ferments" which are so frequently found in their writings of the thirteenth to the fifteenth century. They even speak of the philosopher's stone as fermenting unlimited quantities of lead and mercury into gold.

In the fifteenth century Basil Valentine in his "Triumphal Car of Antimony" claims that yeast employed in the preparation of beer communicates to the liquor an internal inflammation, thereby causing a purification and separation of the clear parts from those which are troubled; but considers alcohol as already existing in the decoction of germinated barley. In 1648, Van Helmont declared fermentation the cause of all chemical action and spontaneous generation, going so far as to give directions for the production of mice, frogs, eels, etc. He clearly observed the production of a special gas (gas vinorum) during alcoholic fermentation and stated that something from the ferment passes into the fermentable substance, developing therein like a seed in the soil, thereby producing fermentation.

Willis, an English physician, in 1659, claimed that all functions of life depended upon fermentation and that diseases were but abnormal fermentations. Both he and Stahl regarded a ferment as a body endowed with a motion peculiar to itself, which it imparts to the fermentable matter. Stahl, in 1697, advanced the following theory: "Under the influence of the internal motion excited by the ferment, the heterogeneous particles are separated from each other, re-combining so as to form more stable compounds, including the same principles but in different proportions. Putrefaction is but a particular case of fermentation." This theory remained unchallenged eighty years.

Lavoisier, by applying the new methods of organic analysis he had invented, quantitatively ascertained the relations between the fermented matter and the products.

Guy Lussac considered oxygen the sole cause of fermentation, putrefaction and decay, by transmitting its motion to the ferment and this again imparted its motion to the loosely combined fermentable mass.

The present theories of fermentation originated with Schwann and Pasteur. It took a century and a half before the experiments which led up to Schwann's theory found a scientific explanation by the work of this chemist. Leuwenhoeck had, in 1680, already noticed that beer yeast was composed of small spheroid globules. Cagniard de Labour declared yeast a plant and the exciter of fermentation.

Schwann's experiments were made to determine the possibility of spontaneous generation. He found that fermentable fluids, when first heated in closed vessels in the presence of oxygen, to the temperature of boiling water, would not ferment. This disproved Guy Lussac's theory that oxygen caused fermentation. He next showed that purified air or oxygen passed into a sterilized fermentable fluid did not induce fermentation; but that this set in with the introduction of ordinary air. He concluded from these experiments that the air was not the exciter, but simply the medium containing it, and that in the floating particles of the atmosphere were organisms capable of developing in the fluid; should these be killed by heat, fermentation would not take place. In his examination of these organisms, although his methods were not absolute, his conclusions that alcoholic ferments are of a vegetable nature were correct.

Instead of general acceptance, Schwann's theory received but little recognition.

Schultze's method of first passing the air entering a sterilized fermentable fluid through oil of vitriol, and that of Schroeder and Dusch of filtering it through cotton can be regarded as modifications of Schwann's experiments. All these experiments conclusively show that the particles in the atmosphere are the exciters of fermentation but do not render them visible.

Pasteur spurred on by the same motive as Schwann—namely, to determine the question of spontaneous generation—made a simple modification of Schroeder and Dusch's experiment, by substituting gun-cotton and achieved most remarkable results. The gun-cotton, containing the particles filtered from the air, was dissolved in ether under the microscope and now for the first time the organisms could be thoroughly examined.

Tyndall's well-known experiment, with the air-tight box coated with glycerine, demonstrated that gravity alone can purify the atmosphere so as to debar fermentation from setting in.

Pasteur's theory is that, "the chemical act of fermentation is essentially a correlative phenomenon of a vital act, beginning and ending with it; there is never an alcoholic fermentation without there being at the same time, organization, development, multiplication of globules, or the continued consecutive life of globules already formed."

The following few examples will serve to show that the slightest changes in nutrients may render them worthless as such to certain ferments and available to others. Organic substances, showing optical rotation; chiefly exist already formed in the animal or vegetable organisms, or they can be easily obtained from such substances formed during vital processes.

When these substances are made synthetically, they are chemically and physically similar to the natural isomers, but usually do not rotate the plane of polarized light. This leads to the belief that these synthetical products consist of active and inactive molecules in such proportions as to neutralize each other.

Pasteur[1] verified this hypothesis by splitting inactive racemic acid into dextro tartaric acid. Neutral ammonium racemate, in a solution to which the proper inorganic salts had been added, was fermented by means of *Penicillium glaucum* and beer yeast. The dextro tartaric acid was consumed and the laevo left.

Lewkowitch[2] took inactive mandelate of ammonia, employing either *Penicillium glaucum* or *Bacterium termo;* in each case at the end of several weeks all the fluids showed more or less dextro rotation. Natural mandelic acid from amygdalin is laevo-rotary; therefore here, as in Pasteur's experiment with racemic acid, it showed that the organisms consumed the naturally produced isomer.

*Sac. ellipsoideus* and split fungi consume the dextro and leave the laevo. The dextro has the same positive as the laevo negative rotation. The melting points and solubility of the right and left are the same, yet we see that these substances chemically and physically the same, save in their opposite rotatory powers, can serve in one case as nutrients to certain organisms and in the other are worthless as such.

### THE MICRO-ORGANISMS OF THE SOIL. *Sacchse.*[3]

These organisms, according to their actions, can be divided into three groups: those oxidizing constituents of the soil; those reducing or destroying the same; and, lastly, those by whose activity the soil is enriched. As regards the first group, the oxidation can take place in two ways—they can either oxidize by assimilating the organic substances of the soil and reducing them to carbonic acid and water, in order to obtain the necessary heat and energy; or they can oxidize by giving off oxygen. The first may be termed intra-cellular, and the second extra-cellular acting organisms. Amongst the intra-cellular we have, primarily, the usual ferments of decay, which assimilate and respire at the expense of the carbon compounds. In some cases the organisms have accommodated themselves to seemingly most remarkable materials for respiration, the combustion of which affords the necessary heat. Thus the iron bacteria of Winograwdski[4] require ferrous carbonate for their life and development, oxidizing the same to oxid. This can be physiologically interpreted as a respiration process, the protoxid of the respiration material becoming the oxid of respiration product.

The sulfur bacteria are equally remarkable. Their cells are distinguishable by containing from time to time granules of amorphous sulfur. These organisms were formerly regarded as causing the formation of hydrogen sulfid in sulfur springs.

Winograwdski[5] claims the reverse to be the case. They do not produce hydrogen sulfid but consume it, burning it partially first to sulfur (which deposits in the cell) and water, then completely to sulfuric acid, which passes out and forms sulfates from the carbonates of the surrounding water. When no more carbonates are present, the combustion of sulfur to sulfuric acid ceases. Physiologically this is also a process of respiration directed towards generating heat and energy; hydrogen sulfid is the respiration material and sulfuric acid the respiration product.

Olivier[6] does not agree with Winograwdski, and De Rey Pailhade[7] claims the existence of a substance philothion in many plants and animal tissues, capable of converting sulfur in the cold to hydrogen sulfid.

Certain nitrification ferments can be regarded as intra-cellular. They may take up ammonia and give it off as nitrates, this process ceasing as in the case of the sulfur bacteria, when no more carbonates are present.

We now come to the discussion of two ferments, the concomitant actions of which have heretofore caused much confusion. Schloesing and Müntz were the first to observe nitrifying ferments, but to Warrington and Winograwdski belong the credit of isolating the nitrous from the nitric ferment, and also the striking discovery of a colorless organism, capable of existing and performing its functions, in a medium totally devoid of organic material—and synthetically producing organic bodies, independent of sunlight. The importance of this discovery cannot be over-estimated.

Warrington[8] obtained organisms from meadow soil, cultivated in a solution of ammonium chlorid and calcium carbonate, which oxidized ammonia to nitrous acid but had no effect on nitrates. Assimilating the carbon of the carbon-dioxid, they require no organic substance for sustenance. They obtain from the oxidation heat of ammonia the necessary energy to dissociate the carbon-dioxid.

Winograwdski[9] obtained the same ferment employing one gm. ammonium sulfate, one gm. potassium phosphate dissolved in one litre Zurich water to which he added basic magnesium carbonate. After inoculating the sterilized fluid with the nitrifying agent, every trace of ammonia disappeared the fifteenth day. (He describes this ferment as being an elongated ellipsoid, the smaller diameter 0.9–1 mkr., the larger 1.1–1.8 mkr.) The organisms congregate about a piece of carbonate, cover it with their gelatinous mass, and as the carbonate disappears the cells take the shape thereof.

Although the two investigators do not quite agree as to the morphological attributes of the ferment, Warrington arrived at the same conclusions as Winograwdski.

Winograwdski[10] has at least succeeded in isolating the ferment which converts the nitrites into nitrates. He employed gelatinous hydrate of silica, impregnated it with a fluid containing cultivated nitrous ferment. This medium was next inoculated with strongly nitrified soil from Quito; shortly afterwards two different organisms formed respective colonies; one of these was the one sought for. It was composed of irregularly shaped rods, dissimilar to the nitrous ferment of the same soils. He has since found this ferment in many other soils; it is capable of converting solutions of nitrites into nitrates.

Strange to say the isolated ferment from Quito does not oxidize ammonia; it produced neither nitrites nor nitrates when sowed in ammoniacal fluids easily nitrified by the nitrous ferment.

In normal soils the nitrate ferment only produces nitrates even in the presence of a large quantity of ammonia, which does not retard the oxidation of the nitrites immediately after their formation.

Müntz[11] claims the existence of an ammoniacal ferment in the soil, which converts organic nitrogen into ammonia, preparatory to nitrification.

## EXTRA-CELLULAR OXIDATION.

In order to oxidize outside of the organisms, oxygen must be evolved by an assimilation process. Assimilation as an oxidizing cause, for conditions prevailing in the soil, has heretofore received no significance, since the evolution of oxygen, according to the generally accepted theories, depended upon light and chlorophyll, consequently the produced oxidation could only occur on the extreme outer surface. An exception to this heretofore unrestricted rule has been found by Engelmann, as well as one by Heräus. According to Engelmann,[12] *Bacterium photometricum* sharply discriminates between lights of different intensity and wave lengths. The influence of light upon the bacteria is directly proportionate to the intensity. When the intensity is suddenly decreased, the bacteria shoot backwards with opposite rotation (the author calling this a terror motion); consequently a well defined illuminated spot, in an otherwise dark drop, serves as a trap for these bacteria.

They cannot leave, since the terror motion causes them to move back into the illuminated field as soon as they come to the dark outline.

The mobile forms principally congregate in the ultra red rays, *i. e.*, physiologically in darkness, and in these, as in the visible parts of the spectrum, in places closely corresponding to the absorption bands of bacteriopurpurin. This constant ratio between absorption and photokinetic action clearly indicates that the prime effect of light is equivalent to the carbon-dioxid dissociating processes of plants containing chlorophyll.

The bacteriopurpurin is a true chromophyll, inasmuch as it converts the actually absorbed energy of light into potential chemical energy. When lights of different color were employed, the evolution of oxygen increased with the absorption of light by the purple bacteria. This shows that the power of developing oxygen is not the specific property of a certain coloring matter, as these organisms contain no chlorophyll.

It is not surprising, therefore, that other organisms, either colored or uncolored, be found to possess the property of assimilating carbon in the absence of light and evolving oxygen. Such a discovery has now been made—Hueppe[13] substantiating a communication from Heräus that certain colorless bacteria produce from humus and carbonates, in the absence of light, a body closely resembling cellulose. Oxygen is liberated but remains unobserved, as it is immediately used to oxidize the ammonia to nitric acid.

The next question is to what extent do the oxidizing organisms partake in the oxidation phenomena actually taking place in the soil? According to E. Wollny,[14] the oxidation of carbon-dioxid is almost completely to be attributed to the activity of small organisms, of which Adametz[15] estimated that there are about 500,000 to 1 gr. soil. As in all such experiments, this conclusion is based upon the fact that no evolution of carbon-dioxid takes place or is forced to a minimum in a sterilized soil, under otherwise favorable conditions.

## LIBERATION OF COMBINED NITROGEN.

This may take place during putrefaction under the greatest possible exclusion of oxygen or during decay in the presence of oxygen. It does not necessarily occur in all cases or may not be observed owing to a reverse concomitant process, *i. e.*, the fixation of nitrogen. Nitrogen losses can be expected during decay on account of the action of the produced nitrous acid upon the amidlike dissociation of humous bodies as well as in the formation of easily dissociable ammonium nitrites. A peculiar case of the disappearance of available nitrogen exists in the reduction of nitrates as noticed by Springer,[16] Gayon and Dupetit,[17] and Deherain and Marquenne.[18]

## ORGANISMS BY WHOSE ACTIVITY THE SOIL IS ENRICHED IN NITROGEN.

A distinction must be drawn between the higher and lower plants. It is a well-known fact that most plants cannot assimilate free nitrogen; whereas there are sound reasons for the belief that the legumes are exceptions to this rule. The explanation has been sought in the tubercles. These tubercles contain a tissue, consisting of thin walled cells, filled with an albuminous substance, consequently they are richer in nitrogen than the roots. They have been regarded by some as pathogenic growths; by others as reserve reservoirs for albumin. We may now conscientiously assume that these tubercles arise through exterior infection and that they are not normal growths.

Hellriegel[19] and Wilfarth, in their great work, state: —"The legumes deport themselves quite differently from the non-leguminous plants respecting the assimilation of nitrogen, whereas the latter for their nitrogen needs are totally dependent upon the nitrogen compounds present in the soil, and their development proportional to such disposable supply—the legumes have, besides the soil nitrogen, a second source from which they can abundantly cover any deficiency existing in the first. This second source is free atmospheric nitrogen. The legumes attain this power by the coöperation of active living micro-organisms. The mere presence of any low organisms in the soil does not suffice to make the free nitrogen serviceable, but it is necessary that certain kinds of organisms enter into a symbiotic relationship with the legumes.

Lupines acquire nitrogen like the other legumes. They starve in a soil free from nitrogen when the presence of low organisms is excluded; but when this is not the case, their growth is normal. The experiments were carried on in sand containing a suitable nutritive solution. Some of the pots were sterilized; to some infusions from soil were added. In all those, and in only those, to which fresh infusions of lupine soil was added the lupines developed normally, bearing the well-known tubercles on their roots and contained, when harvested, conspicuously larger amounts of nitrogen, than the soil and infusion could have given them. Wherever the infusion had not been added, or where it had been sterilized at 100° or even 70°, the development remained abnormal, the production scant; tubercles remained absent and the harvested plants contained less nitrogen than had been offered them."

According to Ward,[20] Breal[21] and Pradmowski,[22] tubercles will grow on plants free from them when infected with an infusion from tubercles of other plants.

Beyrenick[23] has named the infecting organisms, of which there may be many varieties, *Bacterium radicola*. With the growth of the tubercles the behavior of the plant towards nitrogen is changed and the independence just mentioned begins; this has been proved by an almost superabundance of experiments. Still, the explanation of the manner in which the nitrogen is acquired is not definitely settled. The first inference would be that the root-inhabiting bacteria possess the power of assimilating atmospheric nitrogen, and the higher plants, as hosts harboring these bacteria in their roots, can make use of the nitrogen compounds so produced. Thus there would exist a case of symbiosis between split fungi and the higher plants. We cannot be too slow in accepting this seemingly simple explanation—still, the difficulty of a correct interpretation does not alter the fact, that the legumes acquire free nitrogen from the atmosphere, and that the refuse of their roots thus enriches the soil. They may be called nitrogen collectors in contradistinction to the graminaceous nitrogen consumers.

Berthelot[24] has long contended that the free soil can fixate nitrogen; he considers a sandy and clayey nature of the soil essential, it must admit of free access of air, must not be too moist, be rich in potash and poor in nitrogen. Gautier[25] and Drouin claim that the presence of humous substances causes increase of nitrogen.

Soils free from organic substances do not fixate nitrogen, or the gain is slight. The presence of ferric oxid, so long considered capable of fixing nitrogen, has no effect. Berthelot, as well as most investigators in this line, attributes the fixation to the activity of nitrogen-fixing chlorophyll free bacteria. In most cases the amount is much less than that obtained in soils with legumes. No inorganic soil constituents are known to possess the power of fixing nitrogen and it is questionable whether humous substances can directly do this.

In 1881, Atwater claimed that pease during their growth obtained large quantities of nitrogen from the air. Atwater[26] and Woods made another series of eighty-nine experiments; the result will be found in their admirable paper in the American Journal. I will quote the following:—"There was in no case any large gain without root tubercles; but with them, there was uniformly more or less gain of nitrogen from the air. As a rule, the greater the abundance of root tubercles, the larger and more vigorous were the plants and the greater was the amount of atmospheric nitrogen acquired. The connection between the root tubercles and the acquisition of nitrogen, which was first pointed out by Hellriegel, is abundantly confirmed. In a number of these experiments, there was a loss of nitrogen instead of a gain. The loss occurred where there were no root tubercles; it was especially large with oat and corn plants, and largest where they had the most nitrogen at their disposal in the form of nitrates. This loss may probably be due to the decomposition of the seeds and nitrates through the agency of micro-organisms. In brief, the acquisition of large quantities of atmospheric nitrogen by leguminous plants, which was first demonstrated by experiments here and has been since confirmed by others, is still further confirmed by the experiments herewith reported. These experiments in like manner confirm the observation of the connection between root tubercles and the acquisition of nitrogen. There is scarcely room for doubt that the free nitrogen of the air is thus acquired by plants."

Chemists, as a rule, hesitate to accept isolated cell life as modifying and conditioning the action of those more differentiated; yet it seems that all circumstances point to the fact that most reactions taking place between nitrogen and plants are influenced by micro-organisms.

Let us hope that chemistry will, in the near future, score its greatest agricultural triumph, by unveiling the mysteries which still shroud the specific actions of these organisms thus making it possible to supply the demands of a constantly increasing population.

[1] Pasteur, Cr. XLVI-615, LI-298.
[2] Lewkowitch, B. XVI-1505, 1569.
[3] Sacchse, Chem. Cent. Bl. 1889, II-169, 225.
[4] Winograwdski, Bot. Ztg. XLVI-261.
[5] Winograwdski, Bot. Ztg. XLV-489, 513, 545, 569, 585.
[6] Olivier, Cr. CVI-1744.

[7] De Rey Pailhade, Cr. cvi-1683, cvii-48.
[8] Warrington, Chem. News, lxiii-296.
[9] Winograwdski, A. J. P. Sept., 1890.
[10] Winograwdski, A. J. P. v-577, Cr. cxiii-89.
[11] Müntz, Cr. cx-1206.
[12] Engelmann, Bot. Ztg. xlvi-661, 677, 693, 709.
[13] Hueppe, Ntf. Vers. lx.
[14] Wollny, lv St. xxxvi-197.
[15] Adametz, Inaug. Diss., Leipsic, 1886.
[16] Springer, Amer. Chem. Jour., iv-452–3.
[17] Gayon and Dupetit, Cr. xcv-644.
[18] Deherain and Marquenne, Bot. vii-138.
[19] Hellriegel and Wilfarth, Z. Rub. xxv-1-234.
[20] Ward, Bied. Cent. Bl. xvi-787.
[21] Breal, Cr. cvii-397.
[22] Pradmowski, N. Rd. iv-201.
[23] Beyrenick, Bot. Ztg. xlvi-725, 741, 757, 781, 797.
[24] Berthelot, Cr. cvii-207, 852, cvi-638, 1049, 1214.
[25] Gautier and Drouin, cvi-754, 944, 1098, 1174.
[26] Atwater, Amer. Chem. Jour. xii-526, xiii-42.

# PAPERS READ.

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THE INFLUENCE OF AMMONIA ON AMORPHOUS SUBSTANCES TO INDUCE CRYSTALLIZATION. By Dr. E. GOLDSMITH, 658 N. 10th St., Philadelphia, Penn.

[ABSTRACT.]

I. The first fact which I noted was its effect on chlorid of silver which, as is well known, is amorphous when obtained in the ordinary way. If a ten per cent solution of ammonia be added so as to cover the chlorid of silver say half an inch or so, and, after one agitation, be allowed to stand for several days the Ag Cl will wholly crystallize. The forms produced are isometric. My experience shows that the ammonia does not enter into combination with the chlorid of silver.

II. A manufacturer of artificial ice having noticed that his ice plant failed to give results as satisfactory as in former periods, overhauled the machine and discovered an incrustation in the boiler and tubes. The material was black, opaque and about three-sixteenths of an inch in thickness; a portion of this was coarsely crystallized and the remainder was, apparently, amorphous; although under a power of about 110 diameters it, too, proved to be crystallized as was the coarser portion. It was decidedly magnetic.

A chemical investigation proved this incrustation to be magnetite. No iron oxid had been put into the machine; it may form, or rather was formed, by driving air into the system through carelessness. While it is pretty certain that water of ammonia will not act on metallic iron, yet, if air be introduced at the same time an oxidation of the metal is effected.

Just why a portion of the iron should be converted into the ferrous, and another portion into the ferric state is an open question. It is for me only to state the fact that the presence of ammonia caused the amorphous magnetic iron oxid to crystallize. We have before us, therefore, a complete example of synthetic metamorphism.

In the literature which has come under my notice, I have yet to find any statement that water alone can change the amorphous black oxid of iron into a crystallized form. The proved fact shows that ammonia possesses this power to an eminent degree whenever heat is applied and also, I think, at ordinary temperature but with a greater allowance of time.

If this view be correct and admit of verification, then ammonia should be called a mineralizer because of its power to effect metamorphism.

While the list of experiments made by a number of authors who have contributed to the synthesis of magnetite is, of course, limited, yet in none of them has the mineral in question been obtained under such conditions and the observation above noted is, therefore, of some interest in chemical geology.

III. The demonstration of these two facts induced me to test the correctness of my theory regarding ammonia as a metamorphic reagent. The hydrated magnesium oxid is an amorphous substance and, if crystallized, ought to furnish brucite.

One gram of chemically pure hydrated magnesium oxid was introduced with ammonia in a pressure bottle and heated on a steam bath for a period of six hundred hours resulting in an almost complete metamorphosis into—"Nemalite"—the fibrous variety of brucite. The amorphous hydrous magnesium oxid appears, under the microscope, as small globulites.

After heating the mixture to a temperature a little over 180° F. for thirty hours, a sample was drawn and a slide prepared in boiled Canada balsam. The globules had arranged themselves into rows somewhat resembling a string of pearls.

These are called margarites. After heating for sixty hours the sample showed staff-like forms, or longulites. None of these forms had any effect on polarized light. A change occurred after eighty hours heating; polarized light was effected at many points although not in a distinctly recognizable character as regards form; they were evidently crystalloids which are irregular in outline. One hundred hours heating, however, finally effected the formation of microlites. They are mostly fibrous and are occasionally grouped into six-rayed stars, *i. e.*, three microlites crossed at a centre. Some groups were radiated, showing a black cross. Extinction parallel to the longer axis. A comparison with a preparation of native nemalite, from Hoboken, New Jersey, gave indications of its identity in form and optical properties. Several additional slides were prepared but without producing any great change except the gradual growth of the microlites by addition, and the formation, of additional groups.

IV. The last two hundred hours heating of the magnesia hydrate and ammonia in the pressure bottle caused an incrustation to form inside the bottle to such a degree as to render it impermeable to light. The incrusted material was separated from the loose, detached portion, washed, dried, heated in spirits of turpentine, and finally embedded in Canada balsam to ascertain its structure. It resembled as closely as could be the ordinary mesh-like structure of serpentine. A qualitative analysis showing silica, magnesia and water, additional proof of this fact. The strong effect of the ammonia on the glass caused its disintegration thus furnishing the silica to form serpentine.

The fact that carbonic acid gas dissolved in water, although in very small quantity, acts as a mineralizer in limestone regions has been thoroughly proved. The question now arises: Can we assign to ammonia a similar function? In my opinion we can, because, in the first place, there seems to be no water falling on the earth's surface which is entirely free from it and while the quantity in one gallon is not large, yet, in the course of years the sum total is enormous and, secondly, as has been shown by my experiments, ammonia by its catalytic effect on amorphous substances will cause metamorphic changes.

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TRIMETHYL-XANTHIN AND ITS DERIVATIVES. By MOSES GOMBERG, M. S., Ann Arbor, Mich. (Communicated by A. B. Prescott.)

[ABSTRACT.]

THE constitutional formula of caffein as given by E. Fisher rests upon a good deal of substantial experimental evidence. Yet it seemed desirable to furnish additional proofs (1) by the preparation of a tetramethyl-xanthin, analogous to the tetramethyl-uric acid, and (2) by the study of the decomposition products of the hypothetical compound.

Although the results obtained are far from being complete, still it seems best to report them such as they are. The subject is still under investigation. and it is better to report the results in independent sections; their joint connection, it is hoped, will be brought out by a future report. The work thus far carried on was:

(1) Iodo-caffein.
(2) Action of Na upon a mixture of an alkyl-halogen and a halogen-caffein.
(3) Action of Zinc-ethyl upon halogen-caffein.
(4) Action of KCN upon chloro-caffein.

I. There are known two halogen-caffeins: $C_8H_9Cl N_4O_2$, and $C_8H_9$-$BrN_4O_2$. An attempt has been made to prepare an iodo-caffein. The indirect method, by treating each of the first two halogen compounds with NaI, KI, and CaI, under varied conditions of temperature and quantities proved unsuccessful. The direct action of iodin upon dry caffein in anhydrous chloroform resulted in the production of a compound $C_8H_{10}N_4O_2 I_5$. Of the seventy-five per cent. of iodin only sixty per cent. could be estimated by titration with $Na_2S_2O_3$, *i. e.*, only four atoms of iodin are addition atoms, the fifth being that of substitution, or as HI (?).

II. The action of Na upon a mixture of $CH_3I$ and a halogen-caffein in a medium of ether, benzene, toluene, etc., did not give good results owing to the very slight solubility of the halogen-caffeins in those solvents.

III. The action of zinc-ethyl was tried in dilute and concentrated form, in flasks with inverted condenser and in sealed tubes, at temperatures of 80°–160°C., but only in one case did reaction take place. The compound produced was difficult to purify; this necessitated a repetition of the experiment on a larger scale, and the body thus obtained is still under investigation.

IV. By the action of KCN upon chloro-caffein it was intended to obtain cyano-caffein. But contrary to expectation a somewhat different compound was produced:

| Calculated for $C_8H_9(CN)N_4O_2$ | Found. |
|---|---|
| C—49.31% | 46.27% |
| H— 4.12 | 5.13 |
| N—31.96 | 29.70 |

Repeated trials under different conditions gave only confirmatory results. Obtained from hot glacial acetic acid the compound gave, as the mean of three analyses:

C—45.70%
H— 5.12
N—29.63

According to E. Fisher, prolonged action of a dilute alcoholic solution of KCN upon bromo-caffein results in the production of a small quantity of amido-caffein. It is reasonable to suppose that chloro-caffein would behave similarly to the bromo-compound. But the writer supposes that Fisher's compound was not amido-caffein for chloro-caffein certainly does not give that, as is seen by comparing the results above with the following:

Calculated for $C_8H_9(NH_2)N_4O_2$
C—45.90%
H— 5.30
N—33.50

The only explanation is that the compound is a half-saponified cyano-caffein, resulting probably thus:

$$\left\{\begin{array}{l} C_8H_9Cl\,N_4O_2+KCN=C_8H_9(CN)N_4O_2+KCl \\ \qquad C_8H_9(CN)N_4O_2+H_2O=C_8H_9(CO\,NH_2)N_4O_2 \end{array}\right.$$

Further saponification would give:

$$C_8H_9(CO.NH_2)N_4O_2+H_2O=C_8H_9(CO.OH)N_4O_2+NH_3$$

| Calculated for $C_8H_9(CO.NH_2)N_4O_2$ | Found. |
|---|---|
| C—45.56% | 45.70% |
| H— 4.56 | 5.12 |
| N—29.54 | 29.63 |

The production of an acid-amid without the help of either acid or alkali is somewhat rare, but not altogether unusual. The supposition of this being the case here is justified (1) by the elementary analysis of the compound, (2) by the probability of the reaction, and (3) by the behavior of the compound. The latter when treated with alcoholic KOH or strong HCl in sealed tubes at 130°C., or with $H_2SO_4$ at 100°C., gives caffein plus $CO_2$, pointing to the formation of carboxy-caffein which, however, immediately breaks up.

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AN EFFECTIVE CONDENSER FOR VOLATILE LIQUIDS AND FOR WATER-ANALYSIS. By Prof. W. A. NOYES, Rose Polytechnic Inst., Terre Haute, Ind.

[ABSTRACT.]

A SMALL glass tube is selected about twice as long as the internal tube of a Liebig's condenser and having an external diameter a little less than one-half as great as the internal diameter of the tube of the condenser. The tube is bent sharply on itself in the middle and the two ends are bent over so as to form an angle of about 45°. The small tube is then inserted into the lower end of the Liebig's condenser with the bent ends directed upward. The tube and condenser are then connected with the water supply in such a way that the water passes first through the small tube and then through the outer tube of the condenser.

[This paper will be printed in the Journal of Analytical and Applied Chemistry.]

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DI-ETHYL-CARBINAMIN AND ITS CONDUCT TOWARDS NITROUS ACID. By Prof. W. A. NOYES, Rose Polytechnic Inst., Terre Haute, Ind.

[ABSTRACT.]

THE new base, $(C_2H_5)_2CH.NH_2$, was obtained by the reduction of the oxim of di-ethyl-ketone with sodium and absolute alcohol. It boils at 89°–91°. Its specific gravity is $D\frac{20^\circ}{4^\circ} = 0.7487$. It is miscible with water in all proportions. The *chlorid* crystallizes in easily soluble needles which melt at 217°. The *chloro-platinate* is very easily soluble and crystallizes in needles. The *nitrite* forms deliquescent needles which are stable at ordinary temperatures. The aqueous solution of the nitrite can be evaporated over sulfuric acid without decomposition. In this respect, di-ethyl-carbinamin is intermediate in its properties between the "alicyclic" bases of Bamberger and the ordinary alkyl amins, and resembles di-benzyl-carbinamin.[1]

[This paper will be printed in the American Chemical Journal.]

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ON THE DECOMPOSITION OF ACETONE WITH CONCENTRATED SULFURIC ACID. By W. R. ORNDORFF, Assistant Professor of Chemistry, Cornell University, Ithaca, N. Y.

[ABSTRACT.]

PURE acetone, (180 grammes) was treated with concentrated sulfuric acid (300 grammes) in the cold, and the mixture allowed to stand for twenty-four hours. It was then heated to 120° when the reaction began. The products were collected and found to consist of: (1) gases, (2) crude mesitylene, (3) aqueous layer, (4) tar and (5) spent acid.

The gases were found to be sulfur dioxid, carbon dioxid and a gas which burned with a luminous smoky flame and which had some of the properties of allylene. Analyses of this gas, however, showed it to be propane, $C_3H_8$.

[1]Amer. Chem. Jour. 14, 225.

The crude mesitylene after purification was distilled over sodium, and over fifty per cent. was obtained in the form of pure mesitylene. The average yield of the crude mesitylene was thirty-three grammes to 180 grammes of the acetone used.

The higher fractions gave a liquid boiling at 185°–187°, a hydro-carbon boiling at 195°–197°, and a third product, also a hydro-carbon, boiling at 280°–282°.

The liquid boiling at 185°–187° was a colorless fluid with a peculiar aromatic odor, and on analysis and determination of the vapor density it gave figures corresponding to the formula $C_{14}H_{22}O$.

The product boiling at 195°–197° was proved to be identical with isodurene $C_{10}H_{14}$ from the analyses and a study of the substitution products.

The hydro-carbon boiling at 280°–282° was a thick viscous liquid having but little odor and was shown on analysis to have the general formula $(C_3H_4)_x$. Attempts were made to determine the vapor density of this body but without success owing to the fact that it decomposed when heated a few degrees above its boiling point.

The aqueous portion of the distillate was found to contain acetone, mesityl oxid, sulfur dioxid and acetic acid.

The tar was separated from the spent acid, neutralized with caustic soda solution and distilled from an iron retort. On redistillation in a vacuum over sodium fractions were obtained which corresponded to the highest of those resulting from fractioning the crude mesitylene and they were therefore added to these fractions.

The spent acid was examined to determine if any sulfonic acids were present but none were found.

The total amount of acetone decomposed was 6.84 kilogrammes. This required 12.6 kilogrammes of sulfuric acid and gave 1.05 kilogrammes of crude mesitylene. From the crude mesitylene were obtained over half a kilogramme of pure mesitylene, thirty grammes of isodurene, eight grammes of the hydro-carbon $(C_3H_4)_x$ and about five grammes of the compound $C_{14}H_{22}O$. The amount of propane obtained at each distillation was about 100 c.c.

The principal product of the reaction, it will be seen, is mesitylene and this method can be recommended as the best known at present for the preparation of this hydro-carbon.

Owing to the small quantities of the compounds $(C_3H_4)_x$ and $C_{14}H_{22}O$ formed it was impossible to determine any further facts regarding them.

These results are at variance with the statement of Victor Meyer[1] "that mesitylene is only obtained from commercial acetone and *not* from pure acetone by condensation with concentrated sulfuric acid," and also with the statement of Jacobsen[2] "That if pure acetone be used in the reaction no higher boiling products than mesitylene are obtained."

[This paper will be printed in full in the Amer. Chem. Jour.]

[1] Lehrbuch der Organischen Chemie (Meyer & Jacobsen) p. 411.
[2] Ber. der Deutsch. Chem. Gesell. 7, 1432.

THE IODOMERCURATES OF ORGANIC BASES. By Prof. ALBERT B. PRESCOTT, Ann Arbor, Mich.

[ABSTRACT.]

THIS is a report of work done, in the chemical laboratory of the University of Michigan, by Mr. L. F. Kebler, namely: the careful production of the iodomercurates of pyridin, quinolin, and quinin, under stated conditions, and their full elementary analysis, reaching molecular formulæ. In the history of the compounds it appears that the use of potassium mercuric iodid as a reagent for alkaloids was indicated by Boullay in 1827, Bourdorf in 1829, Winkler in 1830, von Planta-Richenau in 1846, and Mayer in 1862, the last-named two employing the reagent in volumetric estimation. In 1858, Groves undertook to establish formulæ for these bodies. Dragendorff in 1874, Lyons in 1886, and Snow in 1888, have determined the quantitative value of "Mayer's Reagent." In 1880, the undersigned reported partial elementary analysis of several vegetable alkaloid iodomercurates, with a discussion of the various proofs of their composition. The present investigation was taken up in the desire to obtain light upon the structure of these bodies, as well as to define their bearing upon analytical methods. Their composition appears to be attended with a degree of variability, wherefore it was deemed prudent to subject them to full elementary analysis, after preparation in purity. Also to bring the iodomercurates of pyridin and quinolin into comparison with those of vegetable alkaloids, in respect to structure. The combustion of the mercury compounds presents difficulties which were only overcome by Mr. Kebler after a good deal of experimentation for a satisfactory method. The results give good support to each of the following formulæ:

| | | |
|---|---|---|
| Iodomercurate of | Pyridin, | $C_5H_5N,Hg(I_2)_2$ |
| " " | Quinolin, | $C_9H_7N,HgI_2$ |
| " " | Quinin, | $(C_{20}H_{24}N_2O_2)_2(HgI_2)_3(HI)_2H_2O$. |

Studies of the structure of this class of compounds should take into account the structure of the iodin compounds, as well as the iodomercurates, of such alkaloids as have a constitution most nearly determinate. These data are yet insufficient for profitable generalization.

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THE ENZYMES OR SOLUBLE FERMENTS OF THE HOG-CHOLERA GERM. By E. A. DE SCHWEINITZ, Department of Agriculture, Washington, D. C.

[ABSTRACT.]

THE paper gives method of detection and isolation of two soluble ferments, formed in the cultures of the hog-cholera germ and refers to their physiological effect. Brief reference is also made to the active principle of the glanders cultures, and their effect.

[This paper will be printed in the Medical News, Phila.]

NOTE ON THE EFFECT OF FERTILIZERS UPON THE JUICE OF THE SUGAR-CANE. By CLINTON P. TOWNSEND, Donaldsonville, La.

[ABSTRACT.]

PRELIMINARY to an investigation of the relative value of fertilization and drainage as means for increasing the yield of sugar from the sugar-cane.

Similar series of experimental plots were planted in two qualities of soil whose main difference has been shown, by chemical analysis, to lie in the relative efficiency of their drainage. Each series comprised the following numbers:—

1. "Normal" Fertilizer.
2. "Normal", but with excess of Nitrogen.
3. "Normal" except for absence of Nitrogen.
4. "Normal" except for absence of Phosphoric acid.
5. "Normal" except for absence of Lime.
6. "Normal" except for absence of Potash.
7. Unfertilized.

The results in tonnage and in juice contents were plotted, showing with approximate accuracy:—

1. There was no direct dependence of tonnage upon fertilization, or such dependence is greatly obscured, as shown by the entirely different form of the curve in the two soils.
2. Total solids of juice vary inversely as the tonnage.
3. Sucrose varies directly as the total solids and inversely as the tonnage.
4. Glucose varies inversely as the total solids and sucrose, and directly as the tonnage.
5. Solids not sugar show no correspondence with any of the above components of the juice, but the curves in the two soils are similar in form, indicating these solids to have been largely determined by the fertilization.

Nos. 2 and 3 probably have little chemical significance, the total solids varying inversely as the tonnage, because evaporation varies in this manner; and sucrose varying approximately as the total solids because it of itself constitutes 70–80 per cent. of these solids. Nos. 4 and 5 are chemical problems.

The paper was illustrated by diagrams.

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SOME POINTS IN CONNECTION WITH THE COMPOSITION OF HONEY. By Prof. H. W. WILEY, Department of Agriculture, Washington, D. C.

[ABSTRACT.]

THREE methods of estimating the water in honey are given, viz.: by direct drying in flat dish; by drying in vacuo; and by dilution and specific gravity.

In general, the results are lowest by the first method, and highest by the third. It is believed that the most accurate results are those given by the second method. They are nearly a mean between those of the first and second methods. The results are based on the drying of forty-two samples. Reducing sugar is determined by treatment with alkaline copper tartrate and subsequent electrolytic precipitation of the copper reduced.

Sucrose is determined by polarization before and after inversion.

Invert sugar is determined by polarization at 0° and 88°. At the latter temperature invert sugar is neutral to polarized light. The difference between the polarization at 0° and 88° gives the total optical disturbance due to invert sugar whence the percentage of invert sugar is calculated by the formula, I $a = \times b$, in which $a =$ difference in polarization between 0° and 88° and $b =$ the percentage of invert sugar necessary to cause a variation of one degree on the cane sugar scale between the temperatures named. For instance, a honey polarizes at 0° — 18.5 divisions of the cane sugar scale and at 88° + 12.5 divisions. The difference is 31 divisions.

Then 31 $\times$ $b$ = per cent of invert sugar. The constant for $b$ has been accurately determined and is 2.273. Therefore 31 $\times$ 2.273 = per cent of invert sugar in the sample = 70.5. So far experience shows a possible variation in the rate of change in polarimetric power of invert sugar in honey as the temperature approaches 0°. This is shown in a few plotted lines giving the actual 0° as compared with the theoretical determined by extending the line between 30° and 88°. A large number of determinations shows the line from 30° to 88° to be straight. Any plus polarization at 88° is to be diminished by the percentage of sucrose present, and then is credited to any solid matter present in excess of the invert sugar-sucrose and ash.

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A METHOD OF POLARIMETRIC OBSERVATION AT LOW TEMPERATURES. By Prof. H. W. WILEY, Department of Agriculture, Washington, D. C.

[ABSTRACT.]

THE usual method of securing a low uniform temperature for polarimetric measurements consists in enclosing the solution to be examined in a jacketed tube through which a current of water at the desired temperature is passed. This method is satisfactory when it is not desired to depress the temperature more than two or three degrees below that of the room in which the readings are made. When, however, the desired temperature is 0°, the above method is wholly inapplicable. Not only is it impossible to maintain the same temperature at both ends of the jacketed tube, but another more serious difficulty is also encountered. The cover glasses, cooled to so low a temperature, become at once covered with moisture making the reading difficult and inaccurate. Carrying instrument and observer into a cold storage room is both expensive and trouble-

some. In addition to this the temperature of such a room is uniformly above 0° and especially so when the heat of the body of the observer is introduced.

The whole difficulty is easily and effectively removed by using the apparatus shown. A large jacket made conveniently of brass is used for holding the observation tube, the cover glasses of which are held in place by the screw caps of the jacket. This jacket is covered with some non-conducting substance. The screw caps of the jacket are provided with hard rubber extension caps carrying a perforated brass tube of the same size, and concentric with the observation tube. The space between the brass tube and the rubber extension cap is filled with fused chlorid of calcium. The end of the hard rubber cap is closed air tight with a glass cover, and the interior of the cap is thus kept perfectly dry, avoiding any deposition of moisture on the cover glasses of the observation tube.

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THE ALBUMINOIDS OF MAIZE. By Dr. GEORGE ARCHBOLD, New York, N. Y.

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A SELECT BIBLIOGRAPHY OF CHEMISTRY. By Dr. H. CARRINGTON BOLTON, University Club, New York, N. Y. [To be printed in the Smithsonian Misc. Coll.]

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COPPER SULFATE AS A MATERIAL FOR STANDARDIZING SOLUTIONS. By Prof. EDWARD HART, Easton, Pa. [To be printed in Journ. Analyt. Appl. Chem.]

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ON THE MECHANICAL DETERMINATION OF THE STEREOGRAPHIC CONSTITUTION OF ORGANIC COMPOUNDS. By Dr. GUSTAVUS HINRICHS, St. Louis, Mo.

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PRESENTATION OF SAMPLES FROM THE SALT MINES OF NEW YORK. By Prof. S. A. LATTIMORE, University of Rochester, Rochester, N. Y.

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EFFECT OF SEDIMENTATION UPON SELF-PURIFICATION OF RUNNING STREAMS. By Prof. WM. P. MASON, Rensselaer Polyt. Inst., Troy, N. Y.

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POST-MORTEM IMBIBITION OF ARSENIC. By Prof. W. P. MASON, Rensselaer Polyt. Inst., Troy, N. Y.

THE VALUE OF A WATER ANALYSIS. By Prof. W. P. MASON, Rensselaer Polyt. Inst., Troy, N. Y.

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ITACOLUMITE FROM NORTH CAROLINA. By LAURA OSBORNE TALBOTT. Washington, D. C.

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NOTES ON A BIBLIOGRAPHY OF MINERAL WATERS. By Dr. ALFRED TUCKERMAN, New York, N. Y.

## TENTH ANNUAL REPORT OF THE COMMITTEE ON INDEXING CHEMICAL LITERATURE.

THE Committee notes with satisfaction a growing appreciation of the Reports on Chemical Bibliography that have been presented to the Chemical Section of the American Association for the Advancement of Science. The Ninth Annual Report was widely circulated, appearing not only in the Proceedings of the A. A. A. S., but also in the Chemical News, the J. Anal. Appl. Chem., the J. Am. Chem. Soc. and the Scientific American.

The Committee congratulates the Section on the fact that these annual reports have in large measure accomplished one of the principal objects sought, viz., that of directing attention to the importance of compiling bibliographies, catalogues and indexes to the voluminous literature of Chemistry. While little systematic work has been undertaken, duplication of labor has been prevented and independent efforts have accomplished much; how much appears in the list of bibliographies forming the Appendix to this Report. Chemists are more and more perceiving the advantages of attaching carefully prepared bibliographies to their monographs; recently this plan has been pursued in the important Bulletins of the Chemical Division of the United States Department of Agriculture. Thus a collection of special bibliographies is gradually forming, destined to be of inestimable value to the chemist. The Committee expresses the hope that this collection will grow in the future much faster than in the past, and suggests that members of the Section of Chemistry seriously consider in what way they can individually contribute to the cause.

During the current year the following indexes have been published.

1. A Bibliography of the Electrolytic Assay of Copper. By Stuart Croasdale. In J. Anal. Appl. Chem. v, pp. 133 and 184 (Mar. and Apr., 1891).

2. An Index to the Literature on the Estimation of Nitrogen by Kjeldahl's Method and its modifications. By Lyman F. Kebler. In J. Anal. Appl. Chem. v, 260 (May, 1891).

3. An Index to the Literature on the Estimation of Nitrogen by all other Methods. By Lyman F. Kebler. In J. Anal. Appl. Chem. v, 264 (May, 1891).

4. Index to the Literature of the Tannins. By Professor Henry Trimble, Ph.M., of Philadelphia. This forms an appendix to: "The Tannins, a Monograph on their History, Preparation, Properties, Methods of Estimation and Uses of the Vegetable Astringents," by the author named. Philadelphia, 1892. Vol. 1, 168 pp., 12mo. The Index occupies pp. 101–165 and the titles are arranged chronologically with an alphabetical index of authors. The whole is admirably printed and obviously exhaustive.

5. Index to the Literature of Angelic and Tiglic Acids from 1842–91. By Henry P. Talbot, Ph.D. Technological Quarterly, Vol. v, Nos. 1 and 2 (Massachusetts Institute of Technology, Boston). Contains an historical summary, and author- and subject-indexes.

6. Bibliography of Analytical and Applied Chemistry for the year 1891. By H. Carrington Bolton. J. Anal. Appl. Chem., Vol. VI, p. 61, 1892.

We chronicle also the following contributions to chemical bibliography:

7. Professor Thomas B. Stillman, in his papers on "Animal, Marine and Vegetable Oils used in Lubrication," has paid especial attention to the bibliography of the subject, grouping under each division of his essay many references to periodical literature and other. (J. Anal. Appl. Chem. v, April, June and December, 1891.)

8. A list of Chemical Synonymes is found on pages 661–675 of the Appendix to "The Scientific American Cyclopedia of Receipts, Notes and Queries." Edited by Albert A. Hopkins. New York, 1892. 8vo. Ill.

9. Prof. Samuel P. Sadtler's "Handbook of Industrial Organic Chemistry" (Philadelphia, 1891, pp. xiv–519, roy. 8vo. Ill.) contains bibliographies at the close of each chapter embracing the following topics:

1. Petroleum and Mineral Oil Industry.
2. Industry of the Fats and Fatty Oils.
3. Industry of the Essential Oils and Resins.
4. The Cane and Sugar Industry.
5. The Industries of Starch and its Alteration Products.
6. Fermentation Industries (Malting, Brewing Wines, Spirits, Vinegar, Flour and Bread).
7. Milk Industries.
8. Vegetable Textile Fibres and their Industries.
9. Textile Fibres of Animal Origin.
10. Leather, Glue and Gelatin.
11. Destructive Distillation Industries.
12. Artificial Coloring Matters.
13. Natural Dye Colors.
14. Bleaching, Dyeing and Textile Printing.

The Bibliographies are chronologically-arranged one-line titles.

Professor S. F. Peckham reports substantial progress on his Bibliography of Bitumen; Professor Arthur M. Comey on his Dictionary of Solubilities, and Dr. Alfred Tuckerman on his Bibliography of Mineral Waters. Dr. Arnold Eiloart of New York has completed the MS. of an Index to the Literature of Stereochemistry; this will appear as an appendix to his review of the subject in the Am. Chem. J. The whole will also be issued independently. Prof. Charles E. Munroe announces Part II of his Index to the Literature of Explosives, to be published shortly. Dr. H. C. Bolton's Select Bibliography of Chemistry has been accepted by the Smithsonian Institution for its Miscellaneous Collections and is in the hands of printers.

H. CARRINGTON BOLTON, *Chairman*,
F. W. CLARKE,
ALBERT R. LEEDS,
ALEXIS A. JULIEN,
JOHN W. LANGLEY,
ALBERT B. PRESCOTT,
ALFRED TUCKERMAN.

APPENDIX TO TENTH ANNUAL REPORT OF COMMITTEE ON INDEXING CHEMICAL LITERATURE.

LIST OF INDEXES TO CHEMICAL LITERATURE.

*Abbreviations* of Titles of Chemical Journals. By H. Carrington Bolton [and others]. J. Anal. Chem. Vol. II, pt. 1. Jan., 1888.

*Amalgams;* Index to the Literature of. By Wm. L. Dudley, in his Vice-Presidential Address to the American Association for the Advancement of Science at Toronto. Proceedings A. A. A. S. for 1889, pp. 161–171, 1890. 8vo.

*Ammonia from Atmospheric Nitrogen*, An Index of Researches upon the Production of. By Ezra J. Ware. Published in Proceedings Michigan State Pharmaceutical Association, 1888. H. J. Brown, Secretary, Ann Arbor, Mich.

*Analytical Chemistry*, Bibliography of, for the year 1886. By H. Carrington Bolton. J. Anal. Chem. Vol. I, pt. 3. July, 1887.
[The same] for 1887. *Idem.* Vol. II, pt. 1. Jan., 1888.
[The same] for 1888. *Idem.* Vol. III, pt. 4. Oct., 1889.
[The same] for 1889. *Idem.* Vol. IV, pt. 1. Jan., 1890.
[The same] for 1890. *Idem.* Vol. V, No. 3. March, 1891.

*Analytical and Applied Chemistry*, Bibliography of, for the year 1891. By H. Carrington Bolton. J. Anal. Appl. Chem. Vol. VI, p. 61, 1892.

*Angelic and Tiglic Acids*, Index to the Literature of. By Henry P. Talbot, Technological Quarterly, Boston. Vol. V, Nos. 1 and 2, 1892.

*Beeswax* and Waxes used in adulterating Beeswax, Bibliography of. By Harvey W. Wiley [Editor]. Foods and Food Adulterants. Part VI. Bulletin No. 13, Division of Chemistry, U. S. Department of Agriculture, Washington, 1892. 8vo, pp. 886–871.

*Butines* and their Halogen Addition Products, Index to the Literature of the (1863–1888). By Arthur A. Noyes. Technological Quarterly, Boston, December, 1888. Published at the Massachusetts Institute Technology.

*Butter*, Bibliography of. By Elwyn Waller. In Second Annual Report of the N. Y. State Dairy Commissioner, 1886.

*Chemistry*, A Bibliography of, for the year 1883, by H. Carrington Bolton. In An Account of the Progress of Chemistry in the Year 1883." Smithsonian Report for 1883. Washington, 1884. 8vo.

[The same] for 1884, 1885, 1886, in Smithsonian Reports for said years.

*Chemistry*, A Bibliography of, for the year 1887. By H. Carrington Bolton. Washington, 1888. Smithsonian Miscellaneous Collections, No. 665, 13 pp., 8vo.

*Columbium*, Index to the Literature of. 1801–1887. By Frank W. Traphagen. Smithsonian Miscellaneous Collections, No. 663. Washington, 1888. pp. [IV], 27, 8vo.

*Copper*, Electrolytic Assay, Bibliography of. By Stuart Croasdale. J. Anal. Appl. Chem. V, 133 and 134. (1891).

*Electrolysis*, Index to the Literature of; 1784–1880. By W. Walter Webb. Annals of New York Academy of Sciences, Vol. II, No. 10, 1882. pp. 44, 8vo.

N. B. This has been translated into French by Donato Tommasi, Paris, 1889.

*Explosives*, Index to the Literature of. Part I. By Charles E. Munroe, Baltimore, 1886. pp. 42, 8vo.

Part II, in press (1892).

*Food Adulteration* and its Detection, Bibliography of. By Jesse P. Battershall. In "Food Adulteration and its Detection." New York, 1887. 8vo.

*Geometrical Isomerism*, A Bibliography of. Accompanying an Address on this subject to the Chemical Section of the American Association for the Advancement of Science at Indianapolis, August, 1890. By Robert B. Warder. Proceedings A. A. A. S. Vol. XXXIX, Salem, 1890, 8vo.

*Heat*, Dictionary of the Action of Heat upon certain metallic Salts, including an Index to the principal literature upon the Subject. Compiled and arranged by J. W. Baird; contributed by A. B. Prescott, New York, 1884. pp. 70, 8vo.

*History of Chemistry*, Outlines of a Bibliography of the. By H. Carrington Bolton. Ann. Lyc. Nat. Hist. Vol. X, pp. 352–361. New York, 1873.

*Honey*, Bibliography of. By Harvey W. Wiley [Editor]. Food and Food Adulterants, Part VI. Bulletin No. 13. Division of Chemistry. U. S. Department of Agriculture, Washington, 1892. 8vo, pp. 871–874.

*Iridium*, Bibliography of the Metal, by Nelson W. Perry, in Prof. W. L. Dudley's paper on Iridium, published in Mineral Resources of the United States, calendar years 1883 and 1884. Washington, 1885. 8vo.

*Light*, Chemical Influence of, A Bibliography of. Alfred Tuckerman. Smithsonian Miscellaneous Collections, No. 785, Washington, 1891. pp. 22, 8vo.

*Manganese*, Index to the Literature of; 1596–1874. By H. Carrington Bolton, Annals of the Lyceum of Natural History, New York. Vol. XI, November, 1875. pp. 44, 8vo.

*Milk*, Bibliography of. By Edward W. Martin. In Second Annual Report of the N. Y. State Dairy Commissioner. 1886.

*Nitrogen*, Estimation of. By Kjeldahl's Method, Index to the Literature. By Lyman F. Kebler. J. Anal. Appl. Chem. V, 260 (1891).

*Nitrogen*, Fixation of Atmospheric. For bibliographical data see Historical Summary on this subject by A. A. Breneman in J. Am. Chem. Soc. XI (1889).

*Ozone*, Index to the Literature of; 1875–1879. By Albert R. Leeds. Annals of the New York Academy of Sciences. Vol. I, No. 12, 1880. pp. 32, 8vo.

*Ozone*, Index to the Literature of, 1879–1883; accompanied by an Historical, Critical Résumé of the Progress of Discovery since 1879. By Albert R. Leeds. Annals N. Y. Academy of Sciences, Vol. III, p. 137. 1884. pp. 16, 8vo.

*Periodicals*, A Catalogue of Chemical. By H. Carrington Bolton. Annals N. Y. Acad. Sci., Vol. III, pp. 159–216. New York, 1885. 8vo. *Also:* Chemical News Print, London, 1886. 12mo. Supplement to [the same]. Ann. N. Y. Acad. Sci. Vol. IV, Feb., 1887. 4 pp, 8vo.

*Periodicals*, Short Titles of, current in 1887. By H. Carrington Bolton. J. Anal. Chem. Vol. I, Part 1, 1887. 4 pp. 8vo.

*Peroxid of Hydrogen*, Index to the Literature of; 1818–1878. By Albert R. Leeds. Annals of the New York Academy of Sciences, Vol. I, No. 13, 1880. pp. 11, 8vo.

*Peroxid of Hydrogen*, Index to the Literature of; 1879–1883. By Albert R. Leeds. Annals of New York Academy of Sciences, Vol. III, p. 153, 1884. pp. 3, 8vo.

*Petroleum*, A Bibliography of. By Prof. S. F. Peckham. Report on the Production, Technology and Uses of Petroleum and its Products. Report of the Census of the United States. Vol. X, 1884. 4to, pp. 281–301.

*Ptomains*, A Bibliography of; accompanies Victor C. Vaughan's Ptomaines and Leucomaines, Philadelphia, 1888. pp. 296–314. 8vo.

*Speed of Chemical Reactions*, Literature of. By Robert B. Warder. Proceedings of the American Assoc. Adv. Science. Vol. XXXII, 1883. pp. 3. 8vo.

*Specific Gravity of Solids and Liquids*, A Table of. The Constants of Nature, Part I (new edition, revised and enlarged). By Frank Wigglesworth Clarke. Washington, 1888. Smithsonian Miscellaneous Collections, No. 659. pp. XI–409. 8 vo.

*Spectroscope*, Index to the Literature of. By Alfred Tuckerman. Smithsonian Miscellaneous Collections, No. 658. Washington, 1888. pp. X–423, 8vo.

*Starch-sugar*, Bibliography of. By Edw. J. Hallock. Appendix E to Report on Glucose prepared by the National Academy of Sciences, in response to a request made by the Commissioner of Internal Revenue. U. S. Internal Revenue, Washington, D. C., 1884. pp. 44, 8vo.

*Tannins*, Index to the Literature of. By Henry Trimble. The Tannins. Philadelphia, 1892. Vol. I, Appendix.

*Tea, Coffee and Cocoa Preparations*, Bibliography of the Literature on. By Guilford L. Spencer. Food and Food Adulterants. Part VII, Appendix A. Bulletin No. 13, Division of Chemistry, U. S. Department of Agriculture. Washington, 1892. 8vo, pp. 991–1009.

*Thermodynamics*, Index to the Literature of. By Alfred Tuckerman. Smithsonian Miscellaneous Collections, No. 741. Washington, 1890. pp. VI–329. 8vo.

*Titanium*, Index to the Literature of; 1783–1876. By Edw. J. Hallock. Annals of the New York Academy of Sciences. Vol. I, Nos. 2 and 3, 1877. pp. 22, 8vo.

*Uranium*, Index to the Literature of. By H. Carrington Bolton. Annals of the New York Lyceum of Natural History, Vol. IX, February, 1870. 15 pp. 8vo.

*Uranium*, an Index to the Literature of; 1789–1885. By H. Carrington Bolton. Smithsonian Report for 1885. Washington, 1885. pp. 36, 8vo.

*Vanadium*, Index to the Literature of. By G. Jewett Rockwell. Annals of the New York Academy of Sciences, Vol. 1, No. 5, 1877. pp. 32, 8vo.

## INDEX TO AUTHORS.

# SECTION D.

# MECHANICAL SCIENCE

AND

# ENGINEERING.

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## ADDRESS

BY

## JOHN B. JOHNSON,

VICE PRESIDENT, SECTION D.

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### *THE APPLIED SCIENTIST.*

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It is my purpose in this address to note the relations of pure and applied science and to endeavor to picture what I conceive to be the field of opportunity, if not of duty, which is now ripening into harvest in the domain of scientific applications of the materials and forces of nature to the comfort, happiness, and progress of society.

What should now be called the ancient culture consisted only in the study of mind and the products of mind. Knowing nothing of the realities of Nature and her laws, never having performed a single scientific experiment which could carry conviction of the truth of something not evolved from the mind itself, thrown thoroughly back upon their own ruminations and chewing over and over again forever the tough and juiceless cuds of philosophic controversy, the great minds of all ages had been able to prove to their entire satisfaction the absolute reality of the ideal and the absolute non-existence of the real. No wonder then that they should utterly ignore such purely sublunary and imaginary things as light and heat, the force of steam, the thunder-bolts of Jove, the winds and the waves, the earthquake and the storm. No wonder that they should consider it vulgar to inquire particularly into the composition of matter, or to study the laws of equilibrium, of gravity, and of force. They speculated on these things it is true, but mostly as mental concepts and not as actual entities to be studied as external realities. And still this ancient and outgrown school has a liberal following, those who study only language, philosophy, history, and mathemathics, who, like bats bathed in sunshine, are utterly oblivious to the beauties and thrilling charm of Nature's ways and means, and though dazed at the wonderful miracles of modern science are still insisting that it is all a mere phantom of the mind. But it is little the scientist cares. He holds the key which unlocks the universe, and he is too busy opening the long-locked doors and classifying the newly discovered treasures to trouble himself with the owls and bats of a darker age. The scientist now sets the pattern for all truth seekers. The method of experimental verification has been adopted by the historian and the philosopher, the minister and theologian. Science has won the battle and we have now but to reap the harvest. And this is as pleasurable as it is profitable. The charm of discovering and promulgating a new universal truth or law, whose applications may not be predicted but dimly imagined, and so adding another sheaf to the world's common stock of knowledge, is quite exquisite and unique. The universality of the fact gives it its charm. To have to descend from the universal to the particular, from the study and contemplation of a general law to particular and utilitarian applications of it, is like calling Dante from the composition of his Divine Comedy to sit in judgment at a police court trial.

And here lies the marked distinction between the pure and the applied scientist. To the pure scientist all truths, so they be universal or general, are of equal interest and value. He cares not if they have no utilitarian application, the stock of truth has been augmented, some other related truths have been explained or supplemented, and pure science acknowledges the obligation, and the discoverer has his reward.

But to the applied scientist that only is good, or is prized, which can be shown to be capable of serving useful ends. It is his business to select from the pure scientists' store of universal truth such as he can use for particular purposes. The pure scientist is to the applied scientist what Columbus was to the Puritan Fathers. Columbus was bent on discovering a world, or at least a new way to a practically unknown world, while the Puritan Fathers came to set up for themselves and their children homes where they would be freed from disagreeable persecution—a purely specific and utilitarian end. And yet the results of this specific utilization of Columbus' discoveries have been so great and fraught with so much good and happiness to the world that we are apt to forget the primary discoverer in our gratitude to the men and women who made so specific use of his great and universal achievement.

So with the applied scientist. From the standpoint of the pure scientist he is a mere plodder—a sort of pot-hunter—seeking the so-called practical ends, solving many knotty and difficult problems it is true, but what has he done when he has solved them? He has but gathered a few apples where his pioneer friend has first planted the orchard. But while we gladly pay this high tribute to our friends who make up the major part of this Association, we cannot ignore the necessity of supplementing their work by finding practical uses for so much accumulated wisdom. Wisdom, like Virtue, is its own sufficient reward to its possessor, but like Virtue also it must have altruistic objects and bring growth and happiness in its train to the unwise and to the less fortunate, or it fails still of being a universal good. Although our pure scientists are glad to see their discoveries put to some good use they have a kind of feeling of commiseration for the poor fellows who must take their second-hand information, a thread here, a shred there, and with the skill and industry of the mechanic, weave it into a particular garment which can serve a useful end. But until this is done, or capable of being done, what claim have our pure scientists upon the generous sympathies of society? If knowledge is to be gained only to be retaught to a few others, it is like the study of a dead language—studied mainly that one may be able to teach it to another teacher of teachers *ad infinitum*. I have no sympathy with the toast once proposed to pure mathematics, "May it never be of any use to any body."

Let us allow then, that science must show utilitarian possibilities before it can rightfully demand public support. Not that the study of Mars is unprofitable because we cannot colonize it and raise corn or cotton upon it, or find a market there for our mowers and threshers, for I can conceive of no more utilitarian science to-day than that which helps to hasten the dawn of the new day of a rational cosmos, past, present and future. But what I mean is that the justification lies in its utility in some direction or other. If this be true, then is not he who discovers the use, the equal of him who discovers the law?

It is a patent fact that the training and natural talent which fits one for the calling of a pure scientist necessarily unfits one, or perhaps fails to fit one, for the business of the applied scientist. Certain it is, the business is best done by these two classes of workers, each keeping to his own field. Without stopping to analyze the requirements of pure science, let us hasten on to the study of the opportunities and duties of him who "makes the scientific application of the materials and forces of nature to the service of man his peculiar business and profession."

Our applied scientist then must have free and intelligent access to the great storehouse of established truth. He must be a scientist at second hand. He must not only follow the progress of science in one field, but in every field in which he undertakes to practise. He must therefore be a constant student. This intimate knowledge pertains not only to laws of the powers and forces of nature but of the materials as well. In fact the amount of scientific knowledge required of him to answer to the description we are now making is something quite beyond the ordinary notions of adequacy. It is not gained in a four, or five, or six years' course in college. The young man who thinks he has finished his theoretical studies when he has left college cannot be included in this category. This breadth of information even the pure scientist does not have for he is of necessity a specialist.

Our applied scientist must know also how to do things. This is the knowledge the mechanic has. In learning his trade he has learned the fruits of the world's experience in doing things. He has learned to do a specific class of things in the best possible way. So before our applied scientist can decide what is to be done or what is best to be done, he must have a large knowledge of mechanical methods. This knowledge the pure scientist does not possess.

Again he must know what needs to be done. To know this he must be a man of affairs. He must be acquainted with the ways of commerce and trade. He must foresee the needs of the immediate future. He must know the difficulties and hindrances of present methods before he can provide remedies. He must also be an economist. He must know the cost of things and the wastefulness of present methods before he can determine whether or not it is worth his while to invent new ones. In fact he must know as much as possible about how the world now does its work if he is to facilitate matters. This kind of knowledge also the pure scientist does not possess.

Here are three fields of knowledge, therefore, with which the applied scientist must be familiar. He must have a knowledge of a wide range of scientific truth, must understand mechanical methods, and he must know the ways of the business and of the industrial world.

But what else must our applied scientist have and be? He must have largely developed in him that *sine qua non* in the profitable solution of all new problems,—Invention. This seems to be one of nature's gifts. It can be cultivated, however. If from early youth one forms a habit of thinking up new ways of doing things, seeking perhaps for those extremities which necessitate invention, preferring to work with poor tools or none at all in order to see what can be done in some new and untried way, tinkering up toys or making new ones; in these and in a thousand other ways a boy may foster and develop the inventive faculty. It is this faculty which suggests the various possible ways of accomplishing a given thing. From his knowledge of affairs our applied scientist sees what needs to be done. His invention suggests a hundred ways to do it. It unconsciously runs to and fro throughout his mental storehouse of acquired facts, both of science and method, and brings to his attention all the possible ways of accomplishing the result. The reason sits in judgment upon this troop of suggestions the fertile invention has marshalled, and selects the one which will best accomplish the end in view, when all things are considered.

Thus we see our applied scientist is at once a student of science, a mechanic, a man of affairs, and an inventor combined in one. Nothing short of this fills the bill. Being a scientist only, he knows not what to do or how to do it. Being a mechanic only, he knows particular ways of doing a given series of things, and he is sure to give you of his little store, whether it serves the purpose or not. Being an executive man he sees what ought to be remedied, but he knows not what to put in its place or how to accomplish any desired end. He probably gets a "practical man" to come and do something, but the chances are very much against this something being the best thing, or the one thing which should have been done. Being an inventor, without the knowledge of either the scientist or the business man, is indeed a misfortune. Our patent laws are a curse to this class of martyrs. A very large proportion of the patents applied for are inoperative from the transgression of fundamental laws, and of the operative ones, perhaps nine-tenths are worthless from there being no demand for the product. Such men waste their lives and their fortunes, and that of their credulous friends in their life-long labor of inventing worthless appliances for doing useless things. They are a burden to their families and to society, for somebody must support them in their profitless and expensive gropings in the dark.

To fit a man for this high calling our technical schools are established. They put a young man in the way of becoming what we have here described. He there learns the elements of a series of sciences and their applications which it is absolutely necessary for him to know. If he precedes or accompanies this training with a considerable amount of shop practice, such as is now given in our Manual Training Schools, or if he spends his vacations at such work, he learns something of the mechanic's art. Supplementing this with a knowledge of the business world, and of men, cultivating a pleasing address, but schooling himself to the strictest honesty of motive and act, both with himself and towards others, he becomes favorably known. If now in addition to these he remains a constant student, and possesses a sufficient amount of invention, he should ultimately become the Applied Scientist *par excellence*. Such a man could safely be consulted in the solution of new problems. And this is the special field of the applied scientist. The duplication or copying of old methods or appliances is the work of the mechanic. The solution of a new problem by the ignorant inventor will bring a long and expensive line of failures and if success is reached it is a sort of happy accident. But our applied scientist should be able to find the successful solution, if there be one, and know before he embodies his ideas in wood or metal or stone, that his project will be a success. The mechanic or the inventor must first build and then operate before knowing. The man who makes the scientific application of matter and force to particular needs his exclusive business and profession should know even before trying it whether or not his method or device will perform its work. But he is not only called upon to make a mechanical success, it must be an economical success. If it does not pay it is still a failure. He must foresee all ordinary mechanical and industrial contingencies before he becomes a safe adviser. With such men to lead, our industrial progress would be marvellous. For such men the world has infinite needs, and they could command inexhaustible capital. But, alas! we have few such men. Few men who can at once see a new thing to be done, devise the best possible solution of the problem, present it to the world by convincing arguments, and carry the project to a successful and profitable issue. These are large men indeed. We have hordes of smaller men who can execute projects when once devised, but few who can safely be trusted to devise original solutions to new and untried problems. Success is usually attained after a long line of failures. In fact it is commonly taken for granted that this must be so. But I believe the day is approaching when even initial failure will be regarded as a professional disgrace, and when we shall have men whose business it will be to solve new problems in the application of science with as much certainty of success as though they were problems in mathematics.

When we see what miracles have been accomplished in a single century of scientific applications, nearly all by a system of blind experimenting and repeated failures or only partial successes; how we have imitated the great motor of the solar system and revivified the world through the agency of heat; how we have obliterated time and space on this little earth and made our antipodes our neighbors; how we have brought near the far-off desert and made it to blossom and bear fruit and so have doubled the size of the habitable world; how "the continuous woods where rolled the Oregon and heard no sound save its own dashings" now teems with happy life and resounds to the hum of wheels and the joyous cries of happy children; how the thought, inspiration, discovery, or learning of one is multiplied a million fold by the press and at once becomes the common property of the world; how the hours of labor are shortened so that all mankind may enjoy sufficient leisure to become learned and cultured if they will; how the comforts of life which formerly could be enjoyed only by kings and princes are now available to every industrious citizen; how the causes and sources of disease have been discovered and largely eradicated so that sickness is to-day almost a crime; when we ponder on these marvellous achievements of one short century of crude empiricism in applying the discoveries of science, what may we not hope for from the endless future with an intelligent direction given to the labors of those who seek to garner the fruit of all science and not only to know the law but to control its operation, to harness the very laws of nature to the car of human progress?

Such is my idea of the present opportunities and responsibilities of the Applied Scientist. If not of as noble or honorable a calling as that of pure science it is not unworthy of the life work of the best minds and of the highest honors the world can bestow. Such men are genuine benefactors. You cannot develop a man spiritually until he first has some of the comforts of life and some leisure in which to cultivate the spiritual graces. It has been well said that the greatest missionaries ever sent out from the civilized to the barbarous have been the civil engineers. The ultimate consequences of these ameliorating conditions cannot be foretold. They certainly are not wholly physical, or material. They are the first stages of any great social development and spiritual evolution.

To this high service therefore are we called. To see that all scientific knowledge is turned into useful channels and that no department of human industry suffers for a want of knowledge already stored away in some pure science granary, to foresee what needs to be done and to discern the best way to do it, is the work of the Applied Scientist, and the further development of such men is the work not only of our Technical Schools, but also of the Applied Science section of this Association.

# PAPERS READ.

**METHOD OF MEASURING THE LOSS OF POWER BY DROP OF PRESSURE BETWEEN CYLINDERS IN MULTIPLE CYLINDER ENGINES.** By Prof. J. E. DENTON, Stevens Institute, Hoboken, N. J.

[ABSTRACT.]

THEOREM: Let the clearance spaces of an engine be filled with steam at admission pressure by cushioning. Then the greatest work to be obtained by expanding any volume of steam admitted up to cut off, is equal to the work due the expansion of this steam with zero clearance, if it be assumed

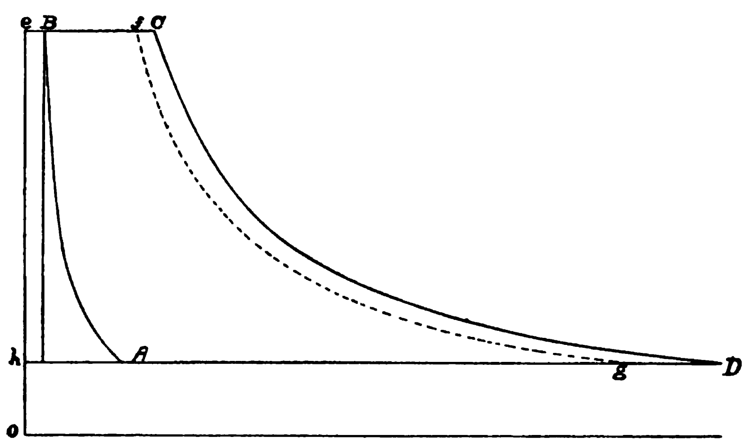


FIG. 1.

that the expansion and compression lines follow the same curve of expansion. Thus in fig. 1, let A B C D be the actual card. B C is the volume admitted each stroke. Lay off $ef$ = B C and draw the expansion line $fg$ by the same law as for B A and C D. Then in $ghef$ = A B C D.

APPLICATION OF THEOREM TO MULTIPLE CYLINDER ENGINES. Let Fig. 2 be the actual combined cards of a compound engine, L M and Q R being cushion lines compressing to admission pressure. Let I and J be points of release. Draw K I and P J parallel to O X. Since L M is a compression line, K I is the volume sent into the low cylinder during exhaust of the high cylinder. Draw K U parallel to O Y. Draw the expansion line I T treating U as the zero of volume, according to any law of expansion common to engines, as say the Marriote, which is the *highest* line generally produced by practice. Then, if there was perfect action, or no loss of pressure between the cylinders, the volume K I by the above prop-

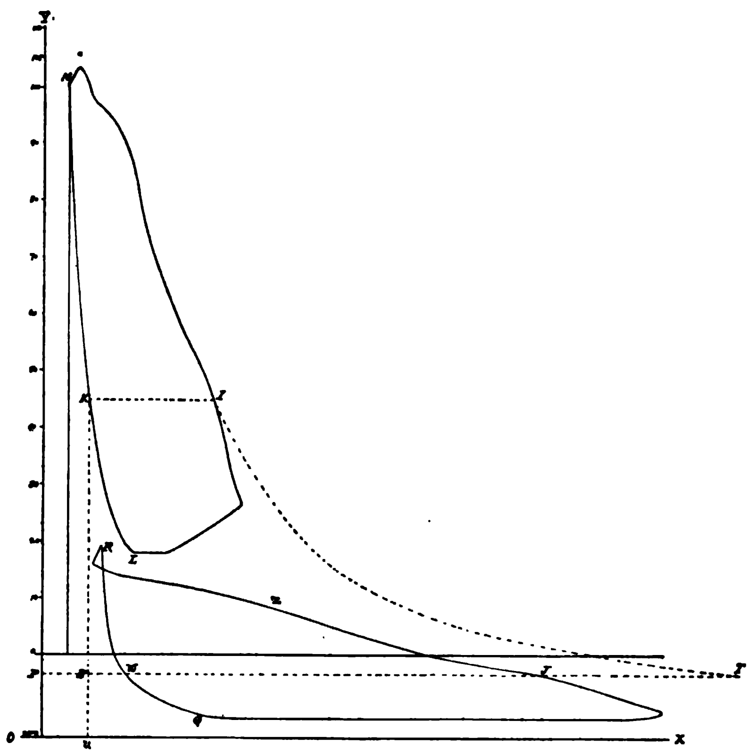

FIG. 2.

osition, should produce the work S K I T before exhaust occurs at J. Hence the difference between the areas S K I T and the actual area J W R Z + K I L measures the loss, and the ratio $\frac{JWRZ+KIL}{SKIT}$ may be taken as a measure of the degree of perfect action. If there is a third cylinder, the volume J W is treated as is K I above and so on for any number of cylinders.

If L M or Q R are part cushion and part lead lines, or if there is no cushion at all, the method still applies, but there is a waste chargeable to uneconomical valve setting, which makes the proposition untrue, inasmuch as the volume K I cannot then produce the area S K I T even if there was no loss of pressure between cylinders due to cylinder condensation.

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STEAM ECONOMY OF THE ENGINES OF THE SCREW FERRY BOAT BREMEN. By Profs. J. E. DENTON and D. S. JACOBUS, Stevens Institute, Hoboken, N. J.

[ABSTRACT.]

THE tests were made by running the ferry boat at a uniform speed over a measured course. The principal data and results obtained are:—

| | | Test No. 1. | Test No. 2. |
|---|---|---|---|
| Cut off in H. P. Cyl. in per cent. of stroke | | 38 | 48 |
| Ratio of expansion, | | 9.6 | 7.4 |
| Boiler pressure in lbs. per sq. inch above atm., | | 98.5 | 68.7 |
| Revolutions per minute, | | 115.4 | 112.8 |
| Total horse power, | | 777.7 | 670.5 |
| Steam per hour per horse power | For all purposes except heating, | 20.7 | 24.7 |
| | Main engines and circulating pump, | 18.6 | 20.5 |
| | Main engines, | 18.1 | 19.9 |
| Per cent. of total steam used by the circulating and vacuum pump, | | 2.8 | 2.6 |

The engine is a double compound having two low pressure cylinders 36″ in diameter and two high pressure cylinders 20″ in diameter. The stroke for all pistons is 28″ The results obtained by this engine compare favorably with those obtained by the triple engine of the screw ferry boat Bergen, as published in the transactions of the American Society of Mechanical Engineers, Vol. XI. The steam for all purposes for the triple engine was 21.7 lbs. per hour per horse power, and for the engine alone 18.3 lbs. Total number of expansions 9.

The reason that the compound shows as good an economy as the triple is that at this low rate of expansion the gain in economy due to clearance and less condensation by the use of three cylinders is counterbalanced by the additional loss of pressure between the cylinders due to passing the steam through the intermediate cylinder. The question is sometimes brought up: Will the economy as shown on a trial trip of a ferry boat be attainable when it is put in service and will have its engines shut down during the time that it is in the slips? This question has been thoroughly investigated in the present and previous tests of ferry boats. The general results obtained are that when the horse power during starting and stopping is carefully allowed for, there is no difference in the economy.

The results of tests made to establish this fact are as follows:—

| | Orange Single-cylinder diameter 46" Stroke 10 ft. | | Bergen Triple-Expansion 18½"×27"×42" Stroke 24. | | Bremen Double-Compound 20"×36" Stroke 28" | |
|---|---|---|---|---|---|---|
| | TRIAL TRIP. | FERRY SERVICE. | TRIAL TRIP. | FERRY SERVICE. | TRIAL TRIP. | FERRY SERVICE. |
| Boiler pressure in pounds per square inch above atmosphere | 23 | 35 | 105 | 140* | 98 | 110 |
| Vacuum in inches of mercury | —— | 27 | —— | 27 | 26 | 24 |
| Revolutions per minute. Average for time engine is running | 24 | 25.4 | 141 | 119 | 115 | 102 |
| Average horse power developed by main engine | 518 | 810 | 665 | 523 | 778 | 603 |
| Ratio of expansion | 2 1 | 2.1 | 9 | 9 | 9 | 9 |
| Steam per hour per horse power of main engine for all purposes | 27.5 | 24.7 | 21.7 | 22.9 | 20.7 | 23.1 |
| Ditto for engine and circulating pump. | —— | —— | —— | —— | 18.6 | 19.9 |
| Ditto for main engine | 27.2 | 24.4 | 18.3 | —— | 18.1 | 19 4 |

* Steam throttled to 100 pounds admission pressure.

The figures given for the Bremen in Ferry service are deduced from data taken by Messrs. Miller, Hill and Ludlow, under the direction of the writers, and constituting their graduating thesis.

[This paper will be printed in "The Stevens Indicator."]

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MEASUREMENT OF TOTAL HEATS OF COMBUSTION. By Prof. D. S. JACOBUS, Stevens Institute, Hoboken, N. J.

[ABSTRACT.]

IN experiments now in progress on gas and oil lamps, it was necessary to measure the heat developed by each, to do which a special device was employed as herein described. The lamps were placed in an air tight box, leading to the bottom and from the top of which were galvanized iron pipes. The top exit pipe was furnished with a damper and a special deflector device to mix the air thoroughly before its temperature was measured. For still further accuracy in measuring the exit temperatures fine thermometers were used at the same cross section of the pipe with their bulbs located at the center, edges and at intermediate positions. Arrangements were made so that radiant heat, either direct or reflected could not affect the readings of the thermometers. The lamps were run at the required candle power and the readings of the temperatures and of an anemometer placed in the inlet pipe carefully noted. After running steadily for about three hours the lamp is taken out and a steam radiator coil put in its place. By regulating the amount of steam that flows into the radiator the temperatures and reading of the anemometer are made the same as for the lamp. The amount of heat given up by the radiator coil is then the same as was given up by the lamp, and may be determined from the weight of steam condensed. To make certain of the quality of the steam entering the radiator it is slightly superheated and its pressure accurately measured. The temperature of the entering steam and of the condensed water leaving the coil is measured by means of thermometers placed in mercury wells. The coil is arranged so that the condensed steam drains readily from it. If any portion of the coil or pipes leading to and from it tends to hold back the condensed steam it will flow from the coil in an irregular way and exact readings cannot be obtained. The condensed steam flows downward to a small standpipe containing a gauge glass in which it is held at a certain height by throttling a discharge valve. It is finally discharged under the surface of cold water so that there is no loss from evaporation. The advantage of this method is that the effect of radiation from the box may be eliminated and that an accurate standardization of the anemometer is unnecessary.

[This paper will be presented at the New York Meeting of the American Society of Mechanical Engineers, Nov., 1892.]

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## USE OF ANEMOMETERS FOR MEASURING THE VELOCITY OF AIR IN FLUMES.

By Prof. D. S. JACOBUS, Stevens Institute, Hoboken, N. J.

[ABSTRACT.]

RECENT experiments involved the use of anemometers for accurately measuring the average velocity of air in flumes. The paper gives the general method finally adopted to standardize the anemometers and states how errors may be involved if other methods are used. The method finally adopted was to impart a known amount of heat to the air passing through the flume, measure the temperatures of the air before and after having the heat imparted to it, and from this data determine the weight and volume of air. Having the volume, the velocity and rate of the anemometers are determined.

The general results shown are that for the low velocities which existed in the tests the average velocity will be the same as that determined by taking an average of a number of the readings of the anemometer if it be placed in all positions in the flume and that if the anemometer be standardized in air at the *same temperature* as that passing through the flume the average for all positions may be relied on. If the anemometer is used in air at a greatly different temperature from that in which it is standardized, the readings will not be reliable and it is for standardizing in hot air that the method herein described is especially useful.

An average velocity cannot be measured by moving the anemometer about the flume in such a way that the observer judges the average will be obtained. Experiments made by differently trained observers show that the results obtained in this way are about 20% too high.

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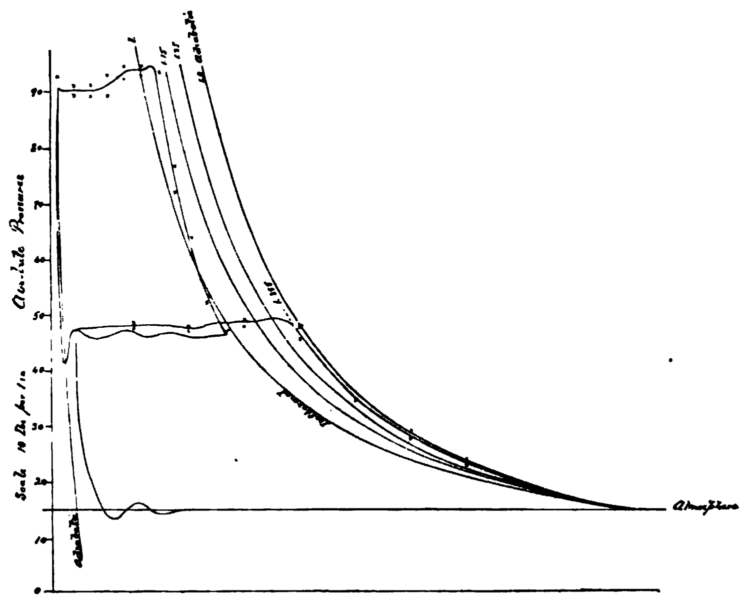
## Relative economy of a single cylinder air compressor with cooling by a spray of water and the present economy of the compound compressors at Quai de la Gare, Paris.

By Fred. Taylor Gause, Stevens Institute, Hoboken, N. J.

[ABSTRACT.]

At the last meeting, the writer presented a paper on the maximum economy attainable by the injection of water as a very fine spray into an air compressor cylinder. The results given in this paper were deduced from



experiments made by Mr. Post and myself for a graduating thesis at the Stevens Institute of Technology. The greatest saving realized, in the experiments presented in that paper, was 33% of that theoretically possible.

In the cards presented at this time, which are taken from the 2000 H. P. compound compressor at Quai de la Gare, Paris, the amount saved is 85% of that theoretically possible. Of this amount only 8% is due to cooling during compression so that the increase of economy in the compound compressor is mainly due to cooling the air between the two stages of

compression. The amount of saving due to cooling during compression is the same as realized in a second set of our experiments, where cooling was effected as at Quai de la Gare, by the water being sprinkled into the cylinder, as a coarse spray.[1]

In the accompanying diagram, the curve with exponent 1.25 is the best result which I realized when compressing in a single cylinder and cooling with a very fine spray. The curve with exponent 1.15 is that which must be realized in a single cylinder to equal the present economy of the compound compressor at Quai de la Gare.

This compressor has two low and one high pressure vertical air-cylinders, each of which is tandem to a steam cylinder of the triple-expansion engine which operates them. The valves of the compressors are "controlled." Their areas are: L. P. inlet 0.095 of cylinder; L. P. outlet 0.077; and outlet of H. P. 0.063 of area of cylinder. The compressors are designed to run at sixty revolutions per minute, though making but forty at the time these cards were taken.

The combined card presents the mean of the six cards taken simultaneously. The maximum and minimum points of the several cards are shown. In one of the low pressure cards some of the points fall outside the adiabatic, which may be due to a slight leak in the delivery valve. Part of the high pressure compression curve falls within the isothermal on account of the air in the intermediate receiver being cooler than the atmosphere, and the volume being diminished by the amount of clearance in the low cylinder.

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BENDING TESTS OF TIMBER, ETC. By Prof. J. BURKITT WEBB, Stevens Institute, Hoboken, N. J.

[ABSTRACT.]

IN making transverse tests of beams of wood, cast iron or any material that is not of uniform strength throughout, the work should be done in such a way as to secure the most accurate results with the least expenditure of labor and material.

The problem may present itself in the shape *a* or *b*.

*a*. The quality of a large lot of beams is to be determined by the breakage of a number of specimens taken at random from the lot.

*b*. A small number of beams of a standard material are to be broken and the average strength of the lot determined.

In the first case economy requires us to determine the quality by breaking as few beams as possible, while in the second case the different tests should not be unnecessarily discordant and therefore of less value.

The problem may be treated mathematically as follows:

Let a beam which is of different strength in different places be represented by a beam of uniform material and of uniform depth, but of a width

[1] At the present time spraying apparatus is being made for the Quai de la Gare compressors. When this is in operation a still greater economy should be realized.

varying so that it shall have the same breaking moment at all points as the original beam. We shall call this the *geometrical* beam; if we regard the real beam as having a certain normal strength except where there are weak places, the geometrical beam will be a parallel beam with certain parts made thinner to represent the weak parts of the real beam.

Calling the width of the parallel part unity, let $r$ be the width of a weak part, and therefore the ratio of the breaking moment at that place to the breaking moment for the parallel part.

To complete the notation, let $l$ be half the length of a beam = half the distance between the two supports upon which it rests. Also let $d$ be the distance from the centre of the beam to either of two equal weights $W$ resting upon it and producing the breaking moment

$$W\,(l-d)$$

When one weight $= 2\,W$ is hung in the centre $d = 0$.

To simplify the problem for presentation here we will suppose the lot of beams to have the same normal strength and the same value of $r$ throughout, interrupted by but one short weak place in each beam, which may exist at any part of its length.

We propose now to show that the ordinary way of testing beams by loading them with a weight 2 $W$ at the centre is uneconomical and unscientific, and that economy depends on the value of $d$.

The moment acting on a beam is uniform and $= W\,(l-d)$ at all points between the two weights; it decreases to 0 at the ends, however, being $= W x$ at any distance $x$ less than $l-d$ from the ends.

It is evident that, if we could be sure of the weak place being exactly in the middle of the beam, there would be no objection to using one weight at the centre and we should arrive at the result desired, *viz.*: the least breaking moment for the lot of beams, by breaking that one beam. It is also evident that with two weights we need only be sure that the weak place lies between them, and that we are the more likely to have this condition in a beam taken at random as we make $d$ greater.

By examining more carefully the case

$$d = 0.$$

we find that, unless the weak place happens to come within the *limiting distance*

$$(1-r)\,l$$

of the centre, it will not cause the beam to fail, and that the *probability* of its coming within that distance is

$$(1-r)$$

Therefore, the *probable number* of beams which must be broken to arrive at their minimum strength is

$$\frac{1}{1-r}$$

But an examination of the case of two weights, or

$$d = d$$

shows that the *limiting distance*, the *probability* and the *probable number* are respectively

$$(1 - r)\,(l - d) + d = (1 - r)\,l + rd;$$

$$(1 - r) + r\,\frac{d}{l} = \frac{l - rl + rd}{l} \text{ and}$$

$$\frac{l}{l - rl + rd}$$

This last expression shows that when $d = 0$ the *probable number* depends entirely upon $r$, and that as $r$ increases, *i. e.*, as the good quality of the beams is increased, the *probable number* increases to infinity for perfect beams. This is as it should be; for we should test an infinite number of perfect beams ($r = 1$) before finding a weak place. Suppose that $r = \frac{3}{4}$, say, then the *probable number* is 4, so that out of every four beams tested three are uselessly broken.

Suppose now that $d = \frac{1}{2}l$ then for $r = 1$ and $r = \frac{3}{4}$ we have for the *probable numbers* only

$$2 \text{ and } \tfrac{8}{5}$$

But $d$ need not be so large; supposing then that $d = \frac{1}{4}l$, the *probable numbers* will be

$$4 \text{ and } \tfrac{16}{7}$$

or, for $d = \frac{1}{8}l$,

$$8 \text{ and } \tfrac{32}{11}$$

We see from this that for values of $r$ ranging from three-quarters to one the number of beams saved by making $d = \frac{1}{4}l$ is from 12 out of every 28 to 28 out of 28, while for $d = \frac{1}{8}l$ it ranges from 12 out of 44 to 44 out of 44 — or, in general, a saving of twenty-five per cent and upwards in favor of testing with two weights instead of one, the saving showing in the decreased number of beams, which must be broken to obtain a result of a certain degree of accuracy.

In cases where it may be desirable to employ the method by two weights without increasing the shearing effect of the weights a beam must be used one-third, or one-seventh, longer according to whether $d = \frac{1}{4}l$ or $\frac{1}{8}l$, which makes low values of $d$ preferable; but this lengthening is not necessary unless the limit of shear is reached and may probably there be avoided by an improved method of attaching the weights and supports.

The suitable value would then seem to be

$$d = \tfrac{1}{8}l \text{ to } d = \tfrac{1}{4}l$$

A variable value of $r$ has been considered with any number of weak places in a beam, and also the effect of the degree of precision required in results, but the outline above given is sufficient for presentation in this abstract.

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## Description of a transmission dynamometer (model exhibited). By Prof. G. W. Hough, Evanston, Ill.

[abstract.]

The transmission dynamometer described, was constructed to be used on a fifty volt dynamo, at the Northwestern University.

It consists of a pulley, in which is coiled a spiral spring, for measuring the torque of the shaft. The use of a spring is not new, but in instru-

ments, hitherto constructed on this plan, the friction of the apparatus has been so considerable as to impair greatly its value as an instrument of precision. In order to make the instrument sensitive to slight changes in the torque, the pulley and sleeve are separated by two rows of steel balls, by this device securing minimum of friction. The amount of torque is measured by the motion of a collar, moved by a worm cut on the prolongation of the axis of the pulley shaft.

It is an instrument of precision.

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NEGATIVE SPECIFIC HEAT. By Prof. DE VOLSON WOOD, Hoboken, N. J.

[ABSTRACT.]

EXTENDING the definition of specific heat so as to include all kinds of specific heat as now used by physicists and engineers—specific heat was defined as the heat that must be absorbed in order to raise the temperature of unity of weight of matter one degree under an assumed law of change of pressure and volume. Three kinds of specific heats are used—that at constant volume, at constant pressure and, in the case of vapors, of constant weight. A formula was then deduced for the specific heat of a pound of fluid a part of which was liquid and the remaining part vapor of that liquid. By means of this it was shown that when water is present with steam, there is a temperature at which the specific heat of the mass is zero, and above that temperature the specific heat is positive and at lower temperatures it is negative. Also when the fluid is all saturated steam, the specific heat is always negative, as was shown in 1850, by both Clausius and Rankine.

It was then shown under what conditions the specific heat of *a perfect gas* may be zero, negative or infinity. Beginning with specific heat at constant pressure, and conceiving the path to be rotated about the initial state, the heat absorbed along any path raising the temperature one degree would be the specific heat for that path, there being constantly a pound of fluid, and the heat so absorbed would diminish until the path coincided with an adiabatic, when it would be zero. Continuing the revolution into the second angle, it was shown that for any right lined path in the second angle heat must be emitted while the temperature is increased giving a negative specific heat. It increases from zero to infinity, the latter being the value when the path is isothermal. In the third angle it will be positive and decrease from infinity to zero, in the fourth angle it will be negative and increase from zero to minus infinity, and positive in the first angle.

When ice is changed to water by the absorption of heat, a finite amount of heat is absorbed at constant temperature, and since the increase of temperature will be zero, the specific heat at this change of state will be infinite. The same is true at the state of changing water to steam.

[This paper will be published in full in the Transactions of the Society of Mechanical Engineers.]

RECENT RESULTS OF MUNICIPAL OWNERSHIP OF GAS WORKS IN THE UNITED STATES. By Prof. EDWARD W. BEMIS, University of Chicago, Chicago, Ill.

IT is quite common in this country to reject the suggestion of city ownership and management of gas works as socialistic, undemocratic and sure to entail such jobbery and political corruptions as to be utterly Utopian. Few disinterested persons who talk this way are aware that in one of the most democratic states of this union, Virginia, nearly every large city does thus own its gas works without any suspicion of uprooting thereby the industrial framework of society, and not only without increase, but if the citizens of those places are to be believed, with a positive diminution of political corruption. Nor is the movement confined to Virginia. Its greater progress, however, there, at least in recent years, may be reasonably ascribed to the greater knowledge the people of that state now have of its effects. The cities owning their works with the date of their adoption of it are as follows: Philadelphia, 1841; Richmond, 1852; Alexandria, Va., 1853; Henderson, Ky., 1867; Wheeling, West Va., 1870; Bellefontaine, O., 1873; Danville, Va., 1876; Charlottesville, Va., 1876; Hamilton, O., 1890; Fredericksburg, Va., 1891. It can be, I think, conclusively proven that while public works may not on the whole manufacture gas cheaper than private companies, yet in the former the citizens and in the latter the stockholders get the benefits of cheap production.

From official sources the following tables are prepared.

TABLE NO. I.

| PLACE. | POPULATION CENSUS OF 1890. | FISCAL YEAR INCLUDED IN RETURNS. | COST OF COAL PER LONG TON. | PRICE OF COKE PER BUSHEL. | COST OF COAL PER M IN HOLDER. | VALUE OF ALL RESIDUALS PER M IN HOLDER | LEAKAGE. |
|---|---|---|---|---|---|---|---|
| Philadelphia, | 1,046,964 | Jan. 1-Dec 31, '92, | 4. | 5½ to 6c. | 40 c. | 14.6 | 14.7 |
| Richmond, | 81,388 | " " " " " | 4.60 | 6 | 28.1 | 11. | 16 |
| Alexandria, | 14,339 | June 1, '91-May 31, '92 | 3.82 | 6½ | 32.8 | 11.2 | 12.4 |
| Henderson, | 8,835 | " " " " " " | 2.61 | 8.6 | 29 1 | 14.6 | 12 |
| Wheeling, | 35,013 | Apr. 1, '91-Mar. 31, '92 | 1.64 | 8½ | 15.2 | 15.4 | 10.3 |
| Bellefontaine, | 4,238 | Jan. 1,-Dec. 31, '91 | 3.34 | 8½ to 10 | 36.1 | 15.1 | 6.4 |
| Danville, | 10,305 | " " " " " | 4.39 | 10 | 45 | 11.8 | 19. |
| Charlottesville, | 5,592 | July 1, '91-June 30, '92 | 3.75 | 10 | | 11. | 6. |
| Hamilton, | 17,565 | Mar. 1, '91-Feb. 29, '92 | 2.59 | 6 | 31 | 28. | 8.1 |
| Fredericksburg | 4,528 | Sept. 1, '91-June 30, '92 | 4.25 | 8 | 44.2 | 11.4 | 18 |

Leakage has been reduced during 1892 from five to twelve per cent. in Danville Fredericksburg and Richmond.

TABLE NO. II.

| PLACE. | NET COST PER M. IN BURNER SAVE EXTENSIONS INT. AND TAXES | COST OF EXTENSIONS PER M. IN BURNER. | COST SAVE TAXES AND INTEREST. | AM'T OF TAXES AT 2% AND INT. AT 5% ON COST OF DUPLICATION. | PRICE OF GAS PER M. | GAS CONSUMED IN BURNER. | COST OF DUPLICATION PER M. | PERCENT OF PROFIT INCLUDING INT. ON COST OF DUPLICATION. |
|---|---|---|---|---|---|---|---|---|
| Philadelphia, | 76c. | 9.5c. | 85.5c. | 20 6c. | $1.50 | 2,857,994,228 | $2.94 | 20% |
| Richmond, | 79.5 | 4.8 | 84.3 | 23.1 | 1.50 | 184,320,000 | 3.30 | 18 |
| Alexandria, | 82.8 | 11.5 | 94.3 | 29.3 | 1.44 | 19,111,157 | 4.18 | 9.8 |
| Henderson, | 58.1 | | 58.1 | 32.3 | 1 25 | 13.004,900 | 4.62 | 12. |
| Wheeling, | 29.5 | 5.8+ | 35.4 | 20 4 | .75 | 138,598 140 | 2.91 | 11.6 |
| Bellefontaine, | 57.7 | 7. | 63.7 | 30.8 | 1.00 | 9 541,100 | 4.40 | 6.2 |
| Danville, | 92.5 | 17.2 | 107.7 | 32.7 | 1.50 | 11,908,300 | 4.67 | 7. |
| Charlottesville, | 46.5 | | 46.5 | 38.8 | 1.50 | 7,[illegible]25,074 | 4.90 | 21.6 |
| Hamilton, | 52.4 | Incl'd'd in Cap. | 52.4 | 34.3 | 1.00 | 35,388,700 | 4.90 | 7.7 |
| Fredericksburg | 127.1 | " " | 127.1 | 47. | 1.50 | 2,665,730 | 8. | 1.2 |

The extensions are usually about the same as above. In Charlottesville and Henderson they average about six cents, though nothing in 1891, and average about ten cents in Wheeling. Whereas in Table II extensions are included under cost of gas making, and where, as in all the ten cities, the extensions and repairs average enough every two or three years to keep the works as valuable as ever if not more so, there is no call to allow for depreciation.

None of the cities except the last pay any taxes. Six pay no interest, being out of debt. Philadelphia, though with little debt, and Danville, have far more than repaid to the city in cash the cost of the works. Hamilton and Fredericksburg, having only just purchased their works, are still in debt for them. The price of gas has been reduced in 1892, in Richmond and Danville, to $1.25.

In competitive business where there is no great risk or rare talent requisite, the capital in the long run cannot exceed the cost of duplication, for otherwise rivals will rush into the business and by forcing prices down to such as yield only normal profits will force down the value of the plant.

While the cost of duplicating gas works in cities of over 30,000 is shown by the experience of public companies to be between $2 50 and $3.50 per thousand feet the capitalization in the twenty-two largest cities of the country averages $7.72, and in eighteen of them $8.78, which indicates the monopoly profits of the gas business.

The experience of Richmond, Va., well illustrates the advantages of city ownership; with gas coal at $4.60 a ton, coke at only six cents a bushel;

with the price of gas at $1.50 and the consumption public and private in 1891, 181.320,000 feet, the city made above all expenses, including repairs, unusual improvements and extensions, the cash sum of $44,646.46. Besides this the city obtained free 51,122,600 feet for public use which at $1.50 per thousand feet was worth $76,683.90. The total profit was thus $121,330.36 or 20.22 per cent. profit on $600,000 necessary, according to the superintendent, to duplicate the works. Even if taxes be deducted, and public companies pay none, the profit would remain fully seventeen per cent. The gas is now sold to consumers at $1.25 per thousand feet.

Most of the cities owning their gas works have entirely paid for them out of their net earnings and have been so much pleased with the results that several have lately constructed city electric light plants, viz., Wheeling, Danville, Alexandria, Charlottesville. Nearly one hundred cities in the United States now own their electric light plants. Almost monthly another city is added to the number. The profit in gas seems greater at present, however, than in electric lighting.

Some, in the face of all this, argue against city ownership of gas works as leading to public ownership not only of street and steam railways, telegraphs and telephones, but of baker shops and factories. As well hold that no one should eat lest he eat too much! Expediency, the result of experience, must determine how far to go and they seem to justify public ownership and management of gas works, water works and electric lights. The same would doubtless be true of the telegraph and telephone.

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EXTENSOMETER FOR MEASURING DISTORTION OF SPECIMENS UNDER TEST. INSTRUMENT EXHIBITED. By Prof. J. B. JOHNSON, Washington Univ., St. Louis, Mo.

[Description of the instrument with cut is published in Engineering News for August, 1892.]

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PECULIAR VISIBLE STRAIN IN STEEL WHEN TESTED IN TENSION COMPRESSION AND CROSS-BREAKING. EXHIBITION OF SPECIMENS AND PHOTOGRAPHS. By Prof. J. B. JOHNSON, Washington Univ., St. Louis, Mo.

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EXHIBITION AND DESCRIPTION OF COMBINED YARD AND METER STANDARD BAR. By Prof. WILLIAM A. ROGERS, Waterville, Me.

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INVESTIGATION OF A 21 FEET PRECISION-SCREW. By Prof. WILLIAM A. ROGERS, Waterville, Me.

A NEW WINDOW VENTILATING APPLIANCE. By A. M. ROSEBRUGH, M.D., Toronto, Canada.

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ON THE USE OF LONG STEEL-TAPES IN MEASURING BASE LINES. By R. S. WOODWARD, U. S. Coast and Geodetic Survey, Washington, D. C. [To be printed in Report U. S. Coast and Geodetic Survey.].

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On Thursday afternoon the members of the Section united with a meeting of the ASSOCIATION OF MECHANICAL ENGINEERING TEACHERS, held in the section room.

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# GEOLOGY AND GEOGRAPHY.

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## ADDRESS

BY

# HENRY S. WILLIAMS,

VICE PRESIDENT, SECTION E.

## *THE SCOPE OF PALEONTOLOGY AND ITS VALUE TO GEOLOGISTS.*

THE scientific study of fossils is scarcely a century old. It was in 1796 that Cuvier for the first time ventured to say that certain fossil bones found in the Paris basin represented an *extinct* species of elephant. About the year 1819, William Smith became famous by proving that rock strata could be traced across the country by their fossils, that at each outcrop across miles of interval a stratum could be recognized by the identity of the fossil shells it contained. Previous to this, fossils had been regarded as curiosities. Cuvier and Smith made it clear that fossils tell us of organisms of whose existence or nature we should otherwise be ignorant, and that the kinds of organism are, somehow, related to the different strata of rocks.

Deshayes, who was a friend of Lamarck, Lyell, and a little later William Lonsdale were among the first to demonstrate the wide scope of paleontology and its inestimable importance in the interpretation of the problems of geology.

Lyell tells us in his Antiquity of Man (Sir Charles Lyell, The geological evidences of the Antiquity of Man: 1870, p. 3) of the method he employed in determining the subdivisions of the Tertiary: "When engaged in 1828" (he writes) "in preparing for the press the treatise on geology, above alluded to [the third volume of 'Principles of Geology'] I conceived the idea of classing the whole of this series of strata according to the different degrees of affinity which their fossil Testacea bore to the living forms.

Having obtained information on this subject during my travels on the continent, I learned that M. Deshayes of Paris, already celebrated as a Conchologist, had been led independently, by the study of a large collection of recent and fossil shells, to very similar views respecting the possibility of arranging the tertiary formations in chronological order, according to the proportional number of species of shells identical with living ones, which characterized each of the successive groups above mentioned."

The view of M. Deshayes may be given in the words of Robert Bakewell, as found in the 5th edition of his geology. He writes:

"M. Deshayes considers that the relative ages of different groups of strata or formations may be determined by their zoological characters alone; that is, by the species of shells they contain. He forms two grand divisions of stratified formations: 1. Those which contain no species of shells analogous to existing species [meaning *identical* species]. This division is stated to comprise all the secondary strata. 2. Strata which contain a greater or lesser number of species analogous to existing species. The last division comprises all the tertiary formations. Again he subdivided this division into three groups, according to the greater or lesser proportion of species of shells that they each contain analogous to living species." (Robert Bakewell, An Introduction to Geology: 5th edition, 1838, p. 399.)

The law here propounded is quite different from that announced by William Smith. "That each stratum contained organized fossils peculiar to itself, and might, in cases otherwise doubtful, be recognized and discriminated from others like it, but in a different part of the series, by examination of them." (Phillips' Memoirs of William Smith, p. 15.)

Smith's law considers only the significance of fossils as marks indicating the stratum to which they belong. Fossils studied and described on this basis, are at best but "Medals of Creation," *i. e.*, the classified signs by which geological formations may be recognized. This is the scope of the older paleontology. The higher or comparative paleontology, as set forth by Deshayes, Lyell and Lonsdale, considers the relationship which fossils bear to each other, to those which preceded them and to their successors. It deals with the history of organisms, and therefore is able to find in fossils themselves the evidence of the order of sequence of the rocks containing them.

I quoted from Bakewell, because he considered Deshayes and Lyell's methods as innovations. When, in 1833, he wrote the preface to the fourth edition of his geology, he expressed his contempt thus:

"Great importance," he writes, "is attached to the study of fossil shells; but the character of the animals that inhabited them, of the power they might possess of modifying the form of the shell under various circumstances, has scarcely been thought of. Some French conchologists are endeavoring to establish the doctrine that fossil conchology, independent of the succession and stratification of rocks, is the only true basis of geology; and a trifling difference in the form of a shell, is deemed sufficient to constitute a new species, and to warrant the most important conclusions respecting the age of the rock formations." (*l.* c. p. ix.)

This was sixty years ago, when the general belief was that species are immutable, and therefore that new creation was necessary to account for distinct species. The geologists recognized the importance of species as indication of the age to which the containing rock belonged, and fossils were regarded as particularly valuable in classifying and identifying the stratified rocks, but the question was raised by Deshayes and Lyell—Is there not a natural sequence in the order of the successive species? Lyell evidently did not for several years realize the full import of the question he propounded when he spoke of the relative affinity of the species.

William Lonsdale, in 1839, made a still higher application of paleontology, in his determination of the fossils of South Devonshire to be of intermediate age between the Carboniferous and Silurian systems, which led Sedgwick and Murchison in the same year to propose a Devonian system as of the same age as the Old Red system, though containing no fossils of the same species.

The conditions were these: "Murchison had recognized the "Carboniferous limestones" and the following "Coal Measures" in northern England containing their characteristic fossils. In the Cheviot hills the "Old Red sandstones" were found below them, with their fish remains. In western England the "Silurian system" with its marine fossils was known to run upward into rocks with similar remains, considered to be the lower Old Red sandstone; and the order, (1) Silurian system, (2) Old Red system, (3) Carboniferous system, it was believed, expressed a continuous stratigraphical series. When certain fossils from the limestones of Newton-Bushel, and other localities in South Devonshire were given Lonsdale to describe, he determined them to be of the age of the Old Red sandstone, in the following way (to use his own language): "It was therefore by combining together this evidence, the presence, in the same series of beds, of shells resembling or identical with Mountain limestone species, of Silurian corals, the *Calceola Sandalina*, and various distinct Testacea, that I was induced to suggest that the South Devon limestones are of an intermediate age between the Carboniferous and Silurian systems, and consequently of the age of the Old Red sandstone:" [Notes on the age of the Limestones of South Devonshire by William Lonsdale, F. G. S. [read March 25, 1840] Trans. Geol. Soc. 2d s., Vol. v, p. 721.)

Sedgwick and Murchison adopted Lonsdale's conclusions without reserve, although they produced radical change in the classification they had already published, and on the strength of them they founded the Devonian System, and said: "This is undoubtedly the greatest change which has ever been attempted at one time in the classification of British rocks," and further, "So far from thinking ourselves rash and hasty in drawing the preceding conclusions, we think we may rather be accused of being over-cautious and tardy in accepting evidence, however opposed to commonly received opinions."

(Sedgwick and Murchison, "On the Physical Structure of Devonshire, etc., Pt. II, on the Classification of the Older Stratified Rocks of Devonshire and Cornwall," Trans. Geol. Soc., 2d s., Vol. v, p. 688.)

This interpretation was not stratigraphical, nor was it a case of correlation by means of common species of fossils, after the William Smith method of paleontology, but it was a case of determining the stratigraphical position of the Devonian fauna by a comparison of its species with those of other faunas from which it differed. It is a typical case of what I would call Comparative Paleontology.

In both of the cases cited it will be noted that the fundamental fact underlying the determinations made, consists in the recognized natural order of sequence of species corresponding to the stratigraphic order of the rocks containing them. It is not probable that any of these early paleontologists understood the full meaning of this sequence, and we are hardly yet able to see how much the studies of the paleontologist have done to establish the derivative theory of evolution. But it is becoming every day more and more apparent that the reason for its great value to geology, and for the grandness of the scope of paleontology is the fact that its subject matter is the record of the history of organisms.

To the comparative paleontologist fossils are hieroglyphics which tell more fully than those of Egypt and Persia of the habits, customs, migrations and environments of the successive races from the beginning of the world. Although the stratigraphic order is all important in reading them, when the clew to the story is found, the fossils are as much more important than the stratigraphy (to the correct interpretation of geology) as the meaning of a sentence is more important than the succession of the words on the page.

But I speak here of the scope of the pure science. Before this audience I would call particular attention to the value of comparative paleontology to the geologist, as a means of determining the structure and development of the earth.

Lyell was the first to use paleontology as a means of classifying geological formations. In establishing the divisions of the Tertiary, *i. e.*, Eocene, Miocene and Pliocene, he made a numerical comparison of the faunas themselves. This method has its imperfections, but the fundamental truth underlying its application is that there is a natural order of succession in the history of organisms whose remains are preserved in the strata. This order of succession is observable in respect of three different sets of characters:

(1) The parts or *organs* of which each individual organism is composed.

(2) The separate *species* existing at any particular time.

(3) The combination of species into *faunas* or *floras* which are associated with certain conditions of environment.

In the first case we know how the organs arise, not ready made, but in each individual by gradual modification of the organless germ one after another the various parts and organs of the adult are perfected. The paleontologist has learned that in some general way, at least, the forms of organs have followed the same law of natural sequence. As among vertebrates, the multirayed fin of the fish, the webbed paddle of the enaliosaur, the paw of the crawling reptile, the hand of man form a natural sequence of development, the later in each case presupposing the preceding stage.

In the second case it is well known that there is a natural succession of species. This succession points to genetic relationship between successive species, and it is an established law of this succession that species most like each other occur near together in the chronologic order, and species of the same genus, presenting the greatest divergence from each other, are also the more widely separated in time.

In the third case it is known regarding living organisms that they present natural association with each other and in adaptation to the various conditions of environment. The law of this association is expressed by the terms fauna and flora. Paleontology teaches that the faunas and floras change, and, as the law of Lyell illustrates, that this change is gradual and in a definite order. The individuality of a fauna can be recognized and can be followed out in its successive changes, and these changes are best explained by the law of adjustment to environment.

In the series of modified organs we see the law of *organic development*, in the series of successive species of a race, the law of *hereditary evolution*, and in the composition and changes of successive faunas the law of adjustive *adaptation to environment*.

It is as expressive of these laws that the fossils become such delicate tests of the chronological order and the geological conditions of the past.

In the interpretation of the divisions of the Tertiary, Lyell observed the law of succession of a single fauna, and, for a single continuous fauna, the gradual accession of new species and extinction of old express a normal law of succession. If, however, two faunas are compared, the number of common species will depend upon the likeness or difference in the environing conditions. To apply the Lyellian principle correctly, it is necessary to compare the successive faunas of the same province, and for the recognition of the province too, it is necessary to consider the possible change of climate, or the effect of the shifting of conditions by elevation or depression of the bottom, or change of relation of surface of sea to surface of the land. This principle involves the fact that each species has a limited life period, but it does not involve, in Lyell's first usage of it, the fact that one species is necessarily descended from another.

Before this latter law was accepted as a fact, the natural sequence of species, and of genera and orders was known. Lamarck had advanced the idea of the spontaneous origin and progressive development of the organisms of the earth, but it is interesting to note the fact that the natural sequence of different orders of beings was generally accepted before it was granted that natural descent was the explanation of the sequence. Deshayes maintained that the species of the Cretaceous were all extinct, and in this fact was found the ground for separating the Tertiary order of rocks from the Secondary, the former alone containing shells identical with those now living.

The laws of geographical distribution, with resultant modifications of those combinations of species called fauna and flora, and the modification of the species themselves in their adjustments to changed environment, are sufficient to explain the imperfections of the Lyellian principle of determining relative antiquity of formations by the mere numerical proportion of recent species they contain, but as a general principle it is satisfactory. The same principle of numerical comparison when applied to genera, families and orders furnished the basis for the classification of the geological series into Cenozoic, Mesozoic and Paleozoic.

The mere numerical comparison of faunas is incapable of very minute application in marking the chronological scale, for the reason that the life period or range of species is often equal to that of a geological period, and the life period of a genus may span two or three systems. In these particulars I refer specially to invertebrates. Land vertebrates express a much greater sensitiveness to changes of environment, but as a means of determining the geological age of strata, they are of such rare occurrence as to be practically useless for the general geologist. Vertebrates when they are present, as well as plants, are of extreme value as time indicators. Thus it is evident that we owe to comparative paleontology, and not to stratigraphy or lithology, the primary classification of the geological scale, and the means of distinguishing the chronological position of each formation.

A second invaluable service of paleontology to geology is found in the application of the law of succession of the great groups of organisms. In the history of vertebrates we are all familiar with the law of succession: (1) Fish, (2) Amphibians, (3) Reptiles, (4) Mammals, and in another line, (3) Reptiles, (4) Reptilian Birds, (5) Birds. The finding of remains of any one of these groups of animals is sufficient evidence that representatives of the lower type had previously existed. The abundance of reptilian remains is certain indication of later age than the Paleozoic; the abundance of mammals, of age later than Mesozoic. In the same way the trilobites are known to be an ancient type, and the decapods a more modern type of Crustacea. The Tetracoralla are older than the Hexacoralla. And a great number of similar instances can be named, where, in a particular class or order of organisms, there is a definite succession in the order of their dominance, and theoretically it is believed in their initiation also.

A third application of Paleontology is made by a comparative study of species of a particular genus, or the genera of an order. In each genus there is observed to be a period of particular abundance before or after which there is more or less rapid diminution in the number of species found. Thus the brachiopods, so abundant all through the Paleozoic rocks, present a definite order of sequence in the genera and families, relative abundance of species of which, irrespective of specific names, is a reliable indication of geological age. The Cambrian is indicated by the abundance of its Obolidæ and other inarticulate genera, the lower Silurian by abundance of Orthidæ and Strophomenidæ, the upper Silurian by numerous genera of Strophomenidæ, Pentameridæ and Rhynchonellidæ, the Carboniferous by dominance of the Productidæ, the Mesozoic by dominance of Terebratulidæ and absence of the Paleozoic types. So, too, the Cephalopods furnish a scale of families which present a natural sequence, the Orthoceratidæ, the Goniatitidæ, the Ceratitidæ, the Ammonitidæ, and the dominance numerically of these several divisions at once testifies to the first half of the Paleozoic, the second half of the Paleozoic, the first half of the Mesozoic, the second half of the Mesozoic, and the absence, or almost total absence of each, to the Tertiary and Recent.

Less is known of the succession of species in continuous series as indicative of order of time. The famous case of the classification of the beds of the Lias by its Ammonites is a characteristic example. Oppel, Wright, Buchman and others have studied the Ammonites peculiar to each stratum and classified and defined successive zones thereby.

The name applied to each zone is the specific name of the Ammonite peculiar to the bed, as

Zone of *Ammonites* (*Aegoceras*) *planorbis*, the planorbis bed;
" " " " *angulatus*, angulatus bed;

and so on, *bucklandi*, *tuberculatus*, *obtusus*, etc., beds.

Although this is not the purely comparative method, but is rather an extension of William Smith's principle of recognition of the beds by their fossils, the comparative element is seen in the succession of distinct species in succeeding, relatively thin beds. The studies of Branco and Hyatt expanded the investigation to a comparative study of the series of Ammonites of a single genus, and brought out thereby the exact laws of succession of the several known representatives of the family and their relation to each other, showing unmistakable succession in series of forms, whose order can be accounted for only as genetic.

Hilgendorf,[1] in his famous study of the *Planorbis* of Steinheim, Waagen[2] with the *Ammonites*, Neumayr[3] with the *Paludinas* and Hörnes[4] in the case of the *Cancellaria*, have traced elaborately the paleontological series of forms of a single genus, illustrating this important principle.

In the case of the Pliocene *Paludinas* examined by Neumayr, a series from below upward was traced, which at the base exhibited a normal *Paludina* (*P. neumayri*) and the latest of the series (*P. hoernesi*) was not only regarded as specifically distinct, but as the type of a distinct genus, *Tulotoma*. (See Neumayr, *l. c.* p. 57.)

Professor Hyatt[5] has elaborately traced out all the known species of the *Arietidæ* in the same way, and arranged the different forms in series exhibiting their chronological mutations. Waagen applied this term "mutation" to the modification of form observed on comparing the successive representatives of such series, to distinguish it from the modifications which are exhibited contemporaneously, and are defined under the terms "variation" and "variety." The series of fossil horses described by Marsh and Huxley is another case in which the "mutations" reached a generic value.

All through the field of paleontology may be found similar series of genera in which the succession is of such a nature as to suggest genetic relationship and to lead to the theoretical construction of phylogenetic lines of descent.

[1] Hilgendorf, *Planorbis multiformis* in Steinheimer Süsswasserkalk, Monatsb. Berlin. Akad. 1866.

[2] Waagen, Formenriche des *Ammonites subradiatus*, Benecke's geognost.-paläontolog. Beiträge, Vol. II.

[3] Neumayr und Paul, die Congerien- und Paludinenschichten Westslavoniens, Abhandl. d. geolog. Reichsanstalt, Bd. VII.

Neumayr, Die Stämme des Thierreiches, 1889, pp. 56, etc.

[4] Hörnes, Die fossilen Mollusken des Wiener Tertiärbeckens, Bd. I.

[5] A. Hyatt, Genesis of the Arietidæ, Mem. Mus. Comp. Zoölogy, Vol. XVI, No. 3, 1889.

Although it may be rightly objected that evidence is in most cases extremely imperfect, and in attempts to fill out paleontological series imagination has been freely used in filling the gaps, there can be no question as to the immense value to geology of the knowledge already acquired in this highly theoretical part of paleontology.

It is the *differences* observed on comparing fossils coming from different horizons and different regions that are of value in these determinations, and not the *numerical proportion* of identical forms, as in the William Smith method of identifying strata. It is the direct interpretation of observed variation and mutation of organic forms into terms of the amount of geological time and the extent of change in environment.

This comparative paleontology, to be accurately used, must deal with the finer details of form and structure, because the evidence of genetic affinity must be perfectly clear before the series can be depended upon as expressive of the true order of evolution.

A remark should be made here upon the limitations to the use of fossils as indicative of geological age. Granting the general proposition that the differences exhibited by different species of the same genus are variations and mutations in the descendants of a common stock, still it is not possible to decide *a priori* what the rate of the modification may have been. Certain modifications are undergone in a season during the ontogenetic development of the individual from the germ cell to the adult. In the same way examination of a large number of cases in different groups of the animal kingdom shows that in many cases there is in the early stage of the life history of a new genus rapid expansion in specific modification, and later on each specific line appears to express only very gradual "mutation" in respect of certain characters in which at its early stage it was definitely variable. In other words, upon studying the life histories of species, there appears good evidence of an *initial stage* in which the species present characters in a plastic state; later these characters became fixed in each genetic line, and the species appear, on this account, to be more distinct in their characters. Hence the amount of difference exhibited between two species will not arbitrarily indicate their distance apart in the genetic series. Also different genera exhibit different rates of mutation. It results therefore that the law of mutation must be studied separately for each genus, and even then the accelerative effect of changed environment is not known, although it is within the reach of investigation.

Another difficulty in the way of close application of these laws in determination of age is the fact that *a priori* it is impossible to tell whether the differences exhibited by two closely allied forms are *varietal* and associated with changed environment, or *mutational* and associated with the paleontological evolution of the race. The study of these problems must therefore be intimately associated with minute regard to stratigraphic sequence, just as in deciphering a manuscript, the succession of the words is essential to a correct interpretation of the writing.

The way in which the paleontological record supplements the stratigraphic evidence is seen in the fact that the paleontology is capable of showing gaps or omissions, the length and nature of which cannot be calculated from the strata themselves.

Another mode of investigation has been employed in which the modifications of a particular part of an organism are made the subject of inquiry. The case of the toes of the ancestors of the horse, from the five toed Eohippus to the one-toed modern horse, the camels, from the Poëbrotherium of the Miocene to the Pliocene and recent Auchenia, as shown in the bones and in the teeth, are examples.

A typical illustration is the case of the development of the sutures of the tetrabranchiate cephalopods.

It will be remembered that the distinguishing feature of the cephalopod shell is its chambers, which separate it from the shell of the gasteropod. The edges of the partitions forming the chambers, where they meet the external walls of the shell, are technically called sutures. In the Nautilian shell, whether exhibiting a simple elongated cone as in Orthoceras, or a curved horn as in Gyroceras or Cyrtoceras, or a close coiled shell as in Nautilus, the sutures are simple. In other groups of chambered shells the suture line is wavy, forming lobes and saddles, or variously crimped, as in Goniatites or Ceratites. These suture lines form a regular series which both in time of initiation and in the period of dominance express a simple law of evolution. Every geologist is familiar with the more apparent features of the series as seen in the genera *Nautilus*, *Goniatites*, *Ceratites* and *Ammonites*.

The various degrees and forms of lobes and saddles are the basis of elaborate classifications and systems of names proposed by Beyrich, the Sandbergers and others, but up to the present time I think we have not a published classification which recognizes the fundamental law of evolution expressed in the series. In analyzing the forms of suture, for my class in the History of Organisms, I found the following simple law to exist: The various suture lines of the chambered cephalopod shells can be distinguished by the differences in degree of complexity of the crimping of the edge of the septum, *viz.:*

(a) In the *Orthoceran* and *Nautilian* type, the edge of the septum is straight, or the curving is not enough to produce more than a single oscillation of the suture line during its complete circumference.

(b) The *Goniatite* septum presents a lobed suture, but the edges of all the lobes and saddles are simple.

(c) In the third type the lobes and saddles are variously crenulated. In the *Ceratite* the crenulation affects the base of the lobes, in *Helictites* the top of the saddles is crenulated, and in *Mendlicottia* the lobes, the saddles and the connecting parts of the suture are crenulated.

(d) In the typical *Ammonite*, there is a tertiary crimping of the suture line, *i. e.*, each of the archings of the line corresponding to the crenulations of *Mendlicottia* is again crenulated, forming a complexly foliate suture.

(e) In the adult forms of *Pinacoceras* there is a still further elaboration of the crimping, the tertiary archings of the Ammonite are again crenulated, forming a quaternary stage of corrugation.

The series presents a gradual elaboration of the crimping of the edge of the septum, forming a suture line, 1st, *simple*, 2d, *primarily lobed*, 3d, secondarily corrugated or the *crenulated type*, 4th, tertiarily corrugated or the *foliate type*, and 5th, the *quaternary corrugations* of Pinacoceras.

In their historical bearings it may be said of this series that,

1st. It is the order in which the various types make their first appearance in the geological series.

2d. It is the order in which the several types become dominant.

3d. It is the order of elaboration in the ontogenetic growth of the individual.

4th. It is the normal order of physical relation borne by the several types to each other; each type is a physical elaboration of the next preceding type.

The convolutions of the suture are crimpings of the edge of a more or less flat disc—the septum—and these convolutions are the simplest mode of adjustment of the edge of such a disc, whose circumference increases more rapidly than its radius.

Considering only the differences in the sutures in the comparison of the several types, it would be correct to state that it would be physically impossible for the Ammonite's septum and suture to be formed without passing through the stages represented by the Nautilus, Goniatites and Ceratites. In other words, the exhaustive analysis of this one element of structure of cephalopod shells shows us that the actual history of the organisms has been exactly that which a serial classification on the basis of differences of this part would suggest, but that no other classification or order of succession could take place by natural descent. It is unnecessary to speak of the value of such series for purely stratigraphical purposes.

This is but one of a great many such mutations to be discovered in the study of comparative paleontology. The general law involved is this: in a series of genetically related forms in which the later representatives present a character which is but the physical elaboration of that found at a much earlier stage, there is implied the presence in the intermediate formations of species in which the character is in an intermediate stage of development, and of a continuous series connecting the extreme forms.

I have thus far spoken of the general scope and application of comparative paleontology. I might cite many cases in which particular problems have been settled by the use of these methods, and refer to the works of Neumayr, Waagen, Kayser, Barrois, Gosselet, Frech, Tscherneyschew, and others in Europe, to the investigations of Hall, Whitfield, Whiteaves, White, Marsh, Cope, Walcott, Herrick, Hill, Prosser, Keyes, Clarke, and of Meek, who was one of the keenest of our earlier paleontologists. And there are many extremely valuable special investigations like those of Agassiz[1] on the echinoids, Hyatt[2] on the cephalopods and those of their followers, Jackson, Beecher and others. But at the present time it will be impossible to speak of them, even were I able to

[1] Revision of the Echini, Cambridge, 1872–74.
[2] See note on p. 157.

do them justice. I will, however, beg your attention to a series of paleontological investigations, with the details of which I am more familiar, and the steps of which are more or less related to each other, and have, collectively, resulted in throwing considerable light upon the geology and geography of the Devonian system.

As I have already said, the Devonian system was originally founded upon purely paleontological evidence. The question as to the lower limit of the Devonian in this country has been a purely paleontological problem, and the reason for including the Oriskany in the Devonian is because the fauna is more closely allied to that of the Looe and Cornwall slates, the Gedinnien and the Coblentzien formations of Europe, than to the Silurian faunas, and presents a larger proportion of species which connect it with the Corniferous faunas above than with the Helderberg below. (See Hall's list of species in 42d Annual Report of New York State Museum.)

The correction of the "Chemung" of Iowa and Missouri and the adoption of de Verneuil's earlier interpretations of the Carboniferous age of the fauna as perpetuated in the Kinderhook group, was settled by the evidence of fossils.

The Hercynian question of Europe was debated on paleontological, not stratigraphical grounds.[1]

In 1881, the minute study of *Spirifera lævis*[2] leading to the prediction that the character by which Davidson distinguished the lower Devonian *Spirifera curvata* from the Carboniferous *Spirifera glabra* would be found upon the higher form as well, which afterwards Davidson confirmed, was the first step toward distinguishing the fauna of the upper Devonian of eastern America from the middle Devonian fauna as to its origin. The suggestive fact in this case was that this rare American upper Devonian spirifer was morphologically more closely allied to a common lower and middle European species than to any preceding American form. This thought led to a thorough dissection of the Devonian faunas of

[1] See Kayser, Die Fauna der ältesten Devon-Ablagerangen des Harzes, Abhand. Geol. Specialkarte von Preussen . . . . Bd. II. Heft 4. p. 247–1878.

Also later discussions by Barrois, Lietze, Frech, Novak and others and review by J. M. Clarke, 42d Annual Report of State Museum of Natural History of New York, 1889, p. 409.

[2] Williams, The life-history of *Spirifer lævis* Hale:—a paleontological study, 1881, Ann. N. Y. Acad. Sc., Vol. II, No. 6.

New York and neighboring states. The series of successive faunas along a common meridian were tabulated and compared.[1] The sections were made parallel to each other and near enough together to make it possible to compare corresponding zones of the several series. By this method the law was established that the composition of a fossil fauna changes on passing geographically from one place to another. Upon tracing single species across these sections it was learned that the mutation of the species, not only may be recognized on passing vertically upward through a continuous section, but that the more direct line of succession was often deflected laterally so that the immediate successor of a particular fauna of one section was found not directly above it in the same section, but at a higher horizon in a section ten or twenty miles distant. This *shifting of faunas* was taken as actual evidence of migration and was interpreted as the result of oscillations of level.

The examination of the remarkable fauna of High Point, at the southern end of Canandaigua lake (the locality of which was first shown me by Mr. J. M. Clarke), furnished me with a still further clew to the solution of the origin of the faunas. I recognized, at once, upon seeing it, that it was related to the Iowa Devonian, and differed widely from the typical upper Devonian of New York, in the midst of which it lay. Further analysis of the fauna led to the discovery that the species peculiar to it apparently had their ancestors in the middle Devonian of Europe rather than in any middle Devonian of America. With this stage of progress I examined the fauna peculiar to the Tully limestone. Much confusion had been thrown about it by the publication of a large number of species as "known" Tully fossils. Special search was made in original localities with the result of eliminating a large number of reported species which were found immediately below the true Tully limestone in the calcareous termination of the Hamilton, where the typical Hamilton fauna is very abundant, and the true fauna which I described[2] as the *Cuboides fauna*, was carefully compared with that of every locality in the world of which I could find report of its presence. The result showed that in eastern America where the Tully appears the fauna of the Cuboides zone begins abruptly, and

[1] Williams, On the Classification of the upper Devonian, Proc. A. A. A. S. Vol. XXIV, 1885.

[2] The Cuboides zone and its fauna; a discussion of methods of correlation. Bull. Geol. Soc., Vol. I, 1890.

from it upward, all through the upper Devonian, is a fauna closely related in its species with the upper Devonian of Europe, Russia, Siberia, China and British America, and down as far as Iowa in the interior, the Nevada Devonian also showing close affinities with this type or fauna. But in Europe, where the statistics are abundant and clear, and so far as evidence bore upon the fact, also in Russia, Asia, and British America, the Cuboides fauna is the natural successor of the middle and lower Devonian of those regions.

Mr. Whiteaves, in his recent studies of the British American Devonian along the Mackenzie River valley,[1] adds many points of confirmation of this view, as in some species, like *Stringocephalus Burtini*, which had not heretofore been known in America, but were characteristic of certain middle Devonian of Europe.

These purely paleontological investigations had proved, with a high degree of certainty, that, relatively speaking, the Tully limestone marks a chronological point in the strata which within relatively small limits may be said to be chronologically and not merely taxonomically the same as the Cuboides zone of Europe and Asia, and, second, that the upper Devonian faunas of these several regions are more closely allied than the typical upper Devonian fauna of New York is to its typical middle Devonian fauna of the same area. This is a very important fact, and the principle involved is of vast importance in further studies of comparative nature. It makes necessary the tracing of the geographical distribution of species in order to get accurate data for the interpretation of their geological succession.

As confirmation, however, of the above conclusion, there has recently appeared a paper by Steinman and Ulrich on the Devonian fossils of Bolivia,[2] in which we are shown the origin of the middle and lower fauna of New York and eastern America.

By the comparison of the Devonian faunas of Bolivia, the Andes, Brazil, Falkland islands and South Africa, Ulrich determines their natural affinities with each other, and with the lower and middle Devonian faunas of eastern North America, and that they are remarkably distinct from the corresponding faunas of Europe and northern Asia. Not only does the presence of peculiar species link together these several regions and separate them from the northern

[1] The fossils of the Devonian Rocks of the Mackenzie River Basin. Contributions to Canadian Paleontology, Vol. I, Part 3. 1891.

[2] Beiträge zur Geologie und Palaeontologie von Südamerika, I Palaeozoische versteinerungen aus Bolivien, 1892.

set of regions, but some of the more characteristic species of the southern hemisphere type, as *Vitulina* and *Leptocœlia*, are abundant and common to many localities and of higher range in the southern hemisphere and are rare or confined to lower horizon in the Appalachian Devonian of North America, thus indicating their extra-limital range in the latter region.

In the determination of the genetic affinities of the faunas of the southern hemisphere with those of the lower and middle Devonian in North America, just as in the tracing of the affinities of the Tully limestone fauna and upper Devonian, it is not the identity of species or the majority of species in contrasted regions that plays the greatest part, but it is the testimony of the somewhat isolated forms, whose local distribution is traceable, and also by the breaks in successive lines of species which are associated together as races, though the species at each stage or in different regions may be described under different names.

In the study of the Cuboides zone, it was such species as *Orthis tulliensis*, *Strophodonta mucronata* var. *tulliensis*, *Rhynchonella venustula*, which told the tale, each differing specifically from any European species, but belonging to races, which in Europe had representative species extending from the Silurian through the Devonian into the Carboniferous system, but in the Appalachian region lacked representatives in the middle Devonian, though well represented in the upper Devonian of New York, and were represented also throughout the Devonian deposits in the Nevada and Iówa areas. The continuance of the European type above this zone in the Appalachian region was also testified to by such species as *Spirifera lœvis* and *Spirifera disjuncta*, *Productus dissimilis* of Hall (*hallianus* of Walcott), *Orthis impressa*, *Rhynchonella pugnus* and others which are well represented in the fauna above the Cuboides zone, but have no forerunners in the Appalachian higher than the lower Helderberg (in rare cases seen in the Corniferous), while in the European faunas there are connecting species all through the middle Devonian, thus pointing to a change of fauna, not by *extinction* of the species, but by *migration* from one region to another. Just as the presence of the bones of *Mylodon*, *Megalonyx*, and the tapir in the United States, now extinct in North America, indicates a former extension of the South American living auna of mammals into this continent.

It was by a similar method that Dr. Ulrich traced the historical relations of the Hamilton fauna of the Appalachian province in eastern North America to the southern hemisphere. In his description of the Bolivian fossils collected by professor Steinman, he made comparison not only with the species, but with the faunas of Brazil collected by Hartt, Derby and Rathbone, and of South African and Falkland islands' faunas described by Salter and Sharpe. The most striking evidence of the affinity of these several faunas was derived from the study of three rather abundant genera of brachiopods; *Leptocœlia, Vitulina* and *Tropidoleptus,* genera which I would describe as old-type genera for this Devonian period, *i. e.*, preserving the form and general characteristics of the lower Silurian Orthidæ and Strophomenidæ but assuming the later character of calcified brachial supports of the *Terebratulas* and *Spiriferidæ.* At least this is the case for the first two genera, and *Tropidoleptus* possesses the punctate structure characteristic of the Terebratulas.

Dr. Ulrich observes that *Leptocœlia* is found in North America, particularly in the eastern part, in Bolivia, on the Falkland islands and in South Africa, but not a single case of it has been reported from the Devonian deposits of the other regions, Europe, Asia and Australia, and that the South African and South American species reach larger dimensions than those of North America (*l. c.* pp. 62, 63).

A point bearing upon the general discussion, which Ulrich did not observe, is the fact that this Leptocœlia fauna extended northeastward as far as Quebec, Maine and Acadia, and in that region is the terminal marine fauna of the Devonian. There was evidently a barrier already separating the European sea from that of the Appalachian region, and the connection with the South American faunas was by the southwest. This in some measure may account for the conspicuous absence of characteristic European types in the Appalachian Hamilton faunas.

In regard to the genus *Vitulina*, Dr. Ulrich remarks that it appears in America, but is there a rare species in the later Hamilton, "While," he says, "it is in South America apparently present in each of the hitherto discovered Devonian regions," viz., the province of Para in Brazil, as reported by Rathbone in Coati Island, Titicaca lake, according to Agassiz and Garman, the province of Sao Paulo, reported by Derby, Central Brazil by Smith, and in Bolivia, in several localities, by Steinman, South Africa, Schenk (*l. c* pp. 73, 74). But it is entirely wanting in Europe, Asia and Australia. These facts show the type to be peculiarly a southern one, but it may still further be remarked that the *Vitulina* is in America isolated and above the horizon of *Leptocœlia*, whereas in Bolivian region it is not only associated with *Leptocœlia*, but is common and appears also in other apparently higher zones in association with *Tropidoleptus*, which later in South America is not found associated with *Leptocœlia* indicating that the North American appearance of the type is extra-limital and later than its greatest dominance in South America.

*Tropidoleptus* shows a different history. It is seen in Europe as well as North and South America and Africa, but in North America it is associated with a southern origin, for while it is particularly a Hamilton species and of the Appalachian province chiefly, it runs up into the upper Devonian of eastern New York, and is seen above the Cuboides zone. But it is wanting in the Mackenzie river basin fauna (Whiteaves, "The Fossils of the Devonian Rocks, etc., 1891), which is the Devonian of European-Asia. In the European fauna it seems to be confined to a lower horizon, the Coblenzien of Europe or the Looe slates, while in America it is more characteristic of the higher part of the Hamilton, and in Central New York is even a Chemung species. It is reported from Illinois and Iowa, but is evidently a rare form in those faunas, and in Nevada, where it is in the lower Devonian as it is in the European faunas. Thus its range in the Devonian deposits of the Appalachian region points to its association with the southern faunas and migration with them after their general separation from the European faunas, whose connection with North American areas was by way of Asia and across the Pacific basin after the close of the Silurian, rather than by any connection across the Atlantic basin.

The other species cited in Ulrich's paper on Fossils of Bolivia support the same conclusion that there was a close relationship existing between the Devonian faunas of South America and South Africa and the fauna in the Appalachian trough, reaching as high as the Hamilton formation, and that this general fauna was distinct from the European-Asiatic fauna of the same period. This differentiation of the lower from the upper Devonian faunas occurring in the Appalachian region, and the tracing of them to centres of geographical distribution in opposite hemispheres of the globe, throw light upon certain other important geological problems concerning the Devonian deposits of North America.

As we follow the elaborate series of Devonian formations of New York southwestward across Pennsylvania, Ohio and Kentucky, we gradually lose the separate members, and black shales become conspicuous in their places, and in Tennessee there is but a thin black shale to represent this whole interval, and in northern Alabama scarcely anything separates the Silurian (in some cases lower Silurian) from the Carboniferous resting unconformably or even conformably upon it. Similar conditions are seen in northern Arkansas, where, about the Ozark uplift, the erosion of the Silurian terrane is such that at the corner of Illinois, Helderberg, Oriskany and even traces of Hamilton are left in place, while further west, the latest is Helderberg, or Niagara, or Trenton, and at extreme points magnesian limestone was the surface rock when the black shale was deposited, to be immediately followed by typical carboniferous fossils. In Texas we find a similar cutting out of the Devonian, and more or less of the upper Silurian, and the Carboniferous following the interval. These facts point to an elevation sufficient to occasion extensive erosion toward the southwest, followed by depression, which gave occasion for the deposition of the black shale over extensive areas.

If we are correct in tracing with Ulrich his Bolivian Devonian fauna to South Africa and recognizing it in the lower and middle Devonian faunas of the Appalachian area of North America, and in nferring, as I have suggested, that the change in fauna at the close of the Hamilton in New York was associated with the arrival of the Cuboides fauna into the Appalachian region, and thus that the upper Devonian is distinctly a European-Asiatic fauna and connected with it across the Pacific down the Mackenzie region, it is evident that the time of the change of these faunas corresponds with the time of the geologic events in the southern central part of the United States, above referred to. The elevation which occasioned the erosion did not take place till the Hamilton period, and the depression and deposit of Black shales followed the incursion of the new fauna, or was, in part, contemporaneous with it. The erosion ceased and the deposition began in the south later than in the north, as is indicated by the fuller representations of the separate deposits at the north than at the south, also by the smaller amount of the deposits, as indicated by the gradually thinning black shale on passing from Ohio across Kentucky to Tennessee and Alabama. It was as early as the age of the Oriskany that the separation of the typical southern from the typical northern faunas took place, and in the extreme northeastern extension of the Appalachian region, the Acadian province of Maine and New Brunswick, we observe that this is the highest marine fauna reached in the Devonian. Elevation evidently shut out access to the sea for this region.

It is from that time on that the faunas of the Appalachian region present their essential relation to the southern hemisphere faunas, and show the absence of the typical European fauna. We assume, therefore, that a barrier was raised that shut off connection with European regions during the lower Devonian. The elevation to the south took place somewhere near the close of the Hamilton, and the theory we propose is that an elevation such as to divert the currents, bringing in first the Cuboides fauna from the northwest and finally replacing entirely the Hamilton by the Chemung as far east as New York is the reasonable explanation of the facts.

The interesting point is that the testimony of the migrating fauna chronologically agrees with the testimony of the oscillation, as recorded in the deposits. All along the southern limits of Devonian exposures in the United States there is indication of an oscillation upward and then downward between the Hamilton and the beginning of the Carboniferous.

The succession of faunas in New York indicates a change at the close of the Hamilton from a fauna whose closest affinities were with the South American faunas, to a fauna whose earlier stages were seen in Iowa, Nevada and the Mackenzie river, and whose affinities were with the Asiatic and European Devonian.

In Arkansas and Tennessee the faunas of the Black Shale indicate that the first marine fauna to appear after the elevation and erosion are of an age as late as the Cleveland shale of Ohio, *i. e.*, the very terminal parts of the Devonian or beginning of the Carboniferous. This event, it will be noticed, is associated with that general elevation of the continent, beginning in the northeast, which is expressed by the cessation of marine faunas, and terminating in the Coal Measures and the final elevation above the surface of the great mass of the continent east of the Mississippi river.

This illustrates the general law of the close relationship between the fossil faunas and their environment. Just as the geologist knows how to interpret the fineness or coarseness of sediments into relative distances from a shore line, so the paleontologist is able to see in the shifting of faunas and the comparison of species evidences of elevation or depression of the marine bottom, which upon reaching sea level produced often the diversion of ocean currents and consequent modification of faunas. By the comparison of extinct faunas he learns to recognize the continuity or the discontinuity of the conditions of environment such as mark geographical areas of distribution of living animals. The fossil faunas, their modifications and their migrations, as indicated by presence, absence, rarity, abundance, size, variation, or mutation of their species, are the sensitive evidences of changing geological conditions upon which the geologist must depend for tying together his disconnected facts. Fossils have too often been regarded as only marks for distinguishing the different geological formations, but the scope of the paleontology of to-day is far wider. The modern conception of the evolution of life has made paleontology the science of the *History of Organisms*. And it is because fossils exhibit in morphological characters the evidence of the ancestry through which they have arisen, and of the conditions of environment through which they have successfully struggled, that they are of such paramount value in all geological investigations in which the elements of time or the order of sequence of events is concerned.

# PAPERS READ.

SUBMARINE VALLEYS ON CONTINENTAL SLOPES. By WARREN UPHAM, 36 Newbury St., Somerville, Mass.

[ABSTRACT.]

ON the Atlantic side of our continent the submarine valleys of the Hudson, St. Lawrence, and other rivers have been described by Dana, Lindenkohl, Spencer, and the present writer. The one of these valleys most perfectly known is the continuation of the present land course of the Hudson river to a distance of about 100 miles into the ocean. The course, width, and depth of this submerged channel have been very accurately determined by special work of the United States Coast Survey, many soundings having been taken along all its extent and on the adjoining ocean bed. Where this valley reaches the outer part of the continental plateau, 300 to 600 feet beneath sea level, a submarine fjord or cañon is cut below the general plain of the ocean bed along a distance of 25 miles, from 80 to 100 miles southeast of Sandy Hook, to a maximum sounding of 2,844 feet in the fjord near its mouth. The edge of the continental plain is submerged 600 feet in the sea, while the eroded fjord itself is more than 2,200 feet deep. This fjord is cut in the seaward continuation of the Quaternary, Tertiary, and Cretaceous beds of Long Island and New Jersey. It proves that this portion of North America has been uplifted to a height at least 2,800 feet greater than now, allowing the Hudson to flow along the bottom of the fjord, during the closing part of the Tertiary era and the beginning of the Quaternary; or the great uplift may have occurred or been repeated during the comparatively late stage of the Quaternary era when the principal interglacial epoch was succeeded by the accumulation of the later ice-sheet.

On our Pacific coast several submarine valleys have been found by soundings, as reported by Prof. George Davidson of the United States Coast Survey. The bottom of the deepest of these, near Cape Mendocino, lies 3,120 feet beneath the sea level where it passes across the general submarine contour line of 600 feet. The fjord or cañon is thus eroded 2,500 feet below the top of its banks. Prof. Joseph LeConte has shown that the uplift of this western side of North America more than 3,000 feet above its present height, as known by the Californian submarine fjords, was during late Tertiary and Quaternary time, and that it was probably contemporaneous with the similar uplift at the east.

Land fjords which indent all our northern and Arctic coasts show that this epeirogenic movement reached to the archipelago north of our continent and to Greenland. Similar land fjords indent the shores of Ireland, Scotland, the Hebrides, Orkney, Shetland and Fāroe islands and the Scandinavian peninsula, attaining a maximum depth in the Sogne fjord, the longest in Norway, 4,080 feet below the sea level. These deeply eroded valleys, now filled by long inlets of the sea, prove that northwestern Europe was likewise lately elevated far above its present height.

The most remarkable known example of submarine valleys is found, however, not in northern or circumpolar latitudes but near the equator. This is the continuation of the channel of the river Congo, on latitude 6° S., to a distance of about 100 miles and a depth of more than 6,000 feet beneath the sea. A map of this wonderful submerged cañon, and a description of the surveys and many series of soundings made for the selection of the best course to lay a submarine cable connecting commercial stations on the African coast, by which the extent and depth of this cañon were ascertained, are given by Mr. J. Y. Buchanan, in the Scottish Geographical Magazine for May, 1887. Previous to Mr. Buchanan's accompanying the party which with a steamship made this survey, he had been engaged in similar observations on the *Challenger* in its well known scientific cruise of three and a half years.

Along its last twenty miles before it enters the ocean, the Congo has a depth of 600 to 1,450 feet beneath the sea level. At the mouth of the river the width of this gully, as Mr. Buchanan calls it, is three miles, and its depth is 2,000 feet. Thirty-five miles out to sea, the width of the gullied submarine valley or cañon is six miles, and its depth 3,440 feet. Its bottom there is 3,000 feet below the adjoining ocean bed of the continental slope. At the distance of 70 miles off shore the general slope has fallen off to the depth of 3,000 feet, and below this the cañon has an additional depth of 3,000 feet more; the sounding to its bottom being 6,000 feet.

Several other submarine valleys of very remarkable character are found on this African coast a few degrees north of the equator, one of which, called the "Bottomless Pit," is also mapped by Mr. Buchanan, with description from five transverse lines of soundings. In this place, near latitude 5° N., the 600 feet submarine contour line approaches within a quarter of a mile of the shore. At the distance of one mile off shore, the width of the gully is less than a mile, with a depth of 900 feet; eight miles off shore, its width is one and a half miles, with a depth of 1,960 feet; and two miles farther seaward, its width has increased to four miles, and the sounding to the bottom of the valley is 2,700 feet. The gradient of ascent at its side averages in some places 40 feet in the distance of 100 feet, being at the rate of 2,000 feet per mile.

Though Mr. Buchanan attributes these submerged cañons to the action of marine currents setting in landward under the lighter fresh water of the rivers, while the land, according to his belief, has held its present relation to the sea level, I think that geologists who have studied the submarine valleys of the eastern and western coasts of North America will confidently refer their origin in Africa, as on our own continental borders, to a formerly greater altitude of the land when it stood higher than now by as great an amount as the depths of the cañons below the ocean's surface.

That the Congo submarine valley is not yet filled with the alluvial silt of the river, which discolors the surface water to the distance of many miles off shore, proves that the subsidence of the land from its former altitude was geologically recent. These great epeirogenic movements of the vast plateau forming the southern half of Africa, like the oscillations before noted in North America and Europe, took place doubtless no longer ago than during the Pleistocene or Glacial period and the closing stage of the preceding Tertiary era.

It seems certain that these earth movements had an intimate relationship with the origin of the great lakes of Africa, and with the accumulation and departure of the North American and European ice-sheets.

Why large areas of the earth's crust have been thus upheaved and afterward depressed, I have attempted to explain in a previous paper on "Probable Causes of Glaciation" (Appendix of Wright's Ice Age in North America). These movements appear to me referable to the earth's contraction, relief being provided between epochs of mountain-folding by the upheaval of continental areas and correlative sinking of sea beds, whereby the earth's volume is diminished This process is well consistent with Dana's doctrine of the general permanence of the continents and oceanic basins; for upheaval of an ocean bed would not diminish but increase the earth's volume.

Between times of mountain-building, portions of the continents have been greatly uplifted and anon depressed. Where such uplifts affected lands in high northern and southern latitudes, they became ice-covered. But at length the weight of the ice-sheet, and cessation of the stress in the earth's crust when late mountain ranges, as the Himalayas, the Sierra Nevada, and the St. Elias range, have been further folded and faulted on overthrust planes, again depressed these elevated areas and induced the rapid dissolution of their land ice.

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## TERMINAL MORAINES IN NEW ENGLAND. By Prof. C. H. HITCHCOCK, Hanover, N. H.

[ABSTRACT.]

THE existence of a terminal moraine to the great ice-sheet was advocated by the author in 1868–9, when he discussed the Geological History of Long Island before the New York Lyceum of Natural History and the Long Island Historical Society. He then stated that the back bone of Long Island was a section of it. Since that time these moraines have been found to extend continuously from Long Island to Dakota; and not less than a dozen of them have been found in Minnesota and Dakota. Owing to the lack of field work in New England it has been generally assumed that these phenomena were wanting at the east, and that the drift occurring there represented only the deposit made by the second ice sheet. Early this year Mr. R. S. Tarr described one of these moraines extending from Cape Ann in Massachusetts to near Turner's Falls upon Connecticut river, one hundred miles in length, in the American Journal of Science.

During the present season the author has identified the peculiar features of these moraines in New Hampshire and Vermont; and is satisfied that three or four lines of them can be identified. The deposits are indicated first, by moraines, either situated upon ledges or smoothed older till; second, immense masses of material, or plains consisting of sand, gravel and boulders that have been washed from the moraines; third, eskers and kames; fourth, the situation of lakes and ponds, being determined by morainic accumulation, and to some extent by the areas of drumlins.

The first line determined is clearly defined, extending from Bartlett through North Conway, Albany, Tamworth, Sandwich and along the south border of Squam Lake. In Albany and Tamworth there are enormous piles of more or less water-worn material, over 200 feet high. In Sandwich the ridge is capped by numerous dumps of boulders and moraine rubbish. In Centre Harbor, outcrops of ledges are very scarce because of the abundance of shoved material. Another marked feature of this moraine is the sand and gravel plains of the Saco Valley in Conway, Fryeburg, Maine, and farther south; and the region of Silver Lake in Madison, and Ossipee Lake in Ossipee. This plain also extends up the valley of Bear Camp river to Sandwich.

To the west of Ashland this moraine may be continued in the formation of Newfound Lake, immense piles of kames and moraines, south of Mt. Cardigan in Alexandria and Grafton, and in the abundant gravel and till about numerous ponds in Canaan and Mascomy Lake in Enfield.

To the south another line of moraines may be indicated by the moraines of Wakefield and Cottonborough, the damming up of the Winnipiseogee lake in Alton, ponds in Gilmanton, Northwood and Barnstead and the great plains of the Merrimack river near and about Concord including its eskers.

Fragments of another line may be indicated in immense piles of moraine rubbish to the south of Moosilauke in Warren, traceable to ponds in Piermont to the west and to the sand plains of the Pemigewasset and Baker's rivers to the south. There may be relics of another line along the principal White Mountains as indicated by kames near Littleton, moraines at Bethlehem Hollow and Carroll. To the south of Mt. Washington there is a very large pile of moraine stuff in Mt. Washington river and to the east in the south part of Gorham. Combining these with the recent accumulation of specimens of boulders from near the top of Mt. Washington for the Columbian Exposition by Prof. W. O. Crosby, it would appear that the trustworthiness of the observations upon this highest summit of New England have not yet been satisfactorily challenged.

The most important of all these moraines seems to extend through both Vermont and New Hampshire, from near Burlington, Vt., to the Rangeley

Lakes in Maine. The author's map of the Surface Geology of Vermont (1861) indicates uncommonly large delta deposits at the mouths of the Winooski and Lamoille rivers, which may have been the wash from a moraine. To the east are the very thick terraces of the Lamoille river, hundreds of ponds in Calais, Woodbury, Elmore and Cabot, much modified drift in the Passumpsic valley and to the north near Lake Memphemagog, abundant kames blocking up the south end of Willoughby Lake, Island Pond, etc. Farther east there is Umbagog Lake in New Hampshire, an expanse of the Megalloway river produced by glacial obstructions, and very likely some of the large adjacent Rangeley Lakes.

It is noticeable that the drumlins of southern New Hampshire are grouped in two or three areas very suggestive of moraines that had been shoved southerly by an earlier ice-sheet, and thus compacted by a later movement of the ice. Their absence in the central and northern parts of the state are equally significant

All these suggested morainic lines trend somewhat north of east. Because of the presence of hills, mountains and valleys, the determination of these lines is much more difficult than in the prairies and level regions of the more western states.

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EXTRA-MORAINIC DRIFT IN NEW JERSEY. By Prof. ALBERT A. WRIGHT, Oberlin, Ohio.

[ABSTRACT.]

THE writer reported recent examinations of the region south of the moraine where glaciated material had been reported to occur, extending from Belvidere on the north, to Trenton on the south. Those which were north of the Musconetcong mountain were explained as having been formed by a temporary extension of the same ice-sheet that formed the moraine. This includes the localities about Oxford Furnace, Washington, Harmony, Phillipsburg, and on Musconetcong mountain, two miles south of Bloomsbury, at an elevation of 760 feet. The striated material at Monmouth Junction, and at Falsington, Pa., near Trenton, was referred to the Columbia formation, a river wash. The two localities at High Bridge and Pattenburg, on the southeastern slope of Musconetcong mountain, were differentiated from those north of the mountain, as being composed of local material, mainly gneissic, and wanting in the northern quartzites and conglomerates which are so conspicuous in the deposits north of the mountain. Search for a continuous drift-sheet, connecting these two deposits with those to the north, was unsuccessful, so that they appear to be isolated and in an unglaciated region. The absence of drift from the large Triassic area of Hunterdon county, and the non-disturbance of the diabase outcrop on Sourland mountain were presented as evidence that no ice-sheet had ever passed over that region.

[This paper is printed in full with map, Oct. No. Amer. Geologist, 1892.]

NOTES BEARING UPON CHANGES IN THE PREGLACIAL DRAINAGE OF WESTERN ILLINOIS AND EASTERN IOWA. By FRANK LEVERETT, Denmark, Iowa.

[ABSTRACT.]

DATA are furnished showing that a broad and deep channel enters the Illinois from the northwest near LaSalle. The data so far as collected bear out the hypothesis that the portion of the Mississippi above the Rock Island Rapids was drained in preglacial times through this channel to the Illinois, instead of down the present Mississippi, there bring decisive evidence that no deep preglacial channel exists along the present course of the river from the Rock Island rapids to Muscatine.

There is a large preglacial valley along the present Mississippi below Muscatine, whose upper course is undetermined, but it seems probable that it was through the region now drained by the Red Cedar and Iowa rivers and it may have embraced the upper Minnesota. Examinations have shown that this channel passes the Des Moines or lower rapids on the west, through Lee county, Iowa, as suggested some years ago by General Warren.

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AN EPISODE IN THE HISTORY OF THE CUYAHOGA RIVER. By PROF. E. W. CLAYPOLE, Akron, Ohio.

[ABSTRACT.]

THIS paper deals with the development of the recent Cuyahoga at the end of the ice-age. North of Akron a peculiar feature is manifested in the present channel which leaves its preglacial path and passes through a rock-cutting about half a mile in length. The causes which led to the deviation form the subject of the paper, in which it is shown that the whole upper channel was filled with the sediment of a lake which formerly existed there. Through this sediment the present river has cut its way, removing a large part of the same. Various details regarding the history and present stage of the river are considered at some length.

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SOME PROBLEMS OF THE MESABI IRON ORE. By Prof. N. H. WINCHELL, Minneapolis, Minn.

[ABSTRACT.]

AFTER briefly mentioning the theories that have been offered for the origin of this ore, the paper states some of the geological environments, and calls attention to the absence in the Mesabi range of Minnesota of the various essential conditions which have been relied on for support for the separate theories in other iron districts. The true explanation of the ore therefore, seems not to have been yet suggested, and the problem remains an unsolved one.

[This paper will be printed in the American Geologist.]

THE CENOZOIC BEDS OF THE STAKED PLAINS OF TEXAS. By Prof. E. D. COPE, 2102 Pine St., Philadelphia, Pa.

[ABSTRACT.]

THE Cenozoic beds referred to are the Loup-Fork, Blanco and Equus beds. Their geographical and stratigraphical relations and their paleontology are described, especial attention being given to the Blanco Fauna, which is intermediate in character between the others.

[This paper will be printed in Report Geological Survey of Texas.]

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ON A NEW FORM OF MARSUPIALIA FROM THE LARAMIE FORMATION. By Prof. E. D. COPE, 2102 Pine St., Philadelphia, Pa.

[ABSTRACT.]

THIS genus displays its marsupial character in the inflected inferior border of the mandible. It presents the peculiarity of true molars, $\frac{3}{3}$-tubercular, with four simple premolars, well-developed canines and probably small incisors; and farther, in the molar function of the premolars. The genus was named Thlæodon.

[This paper will be printed in American Naturalist.]

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PALEOBOTANY OF THE YELLOW GRAVEL AT BRIDGETON, N. J. By ARTHUR HOLLICK.

[ABSTRACT.]

A LITTLE more than ten years ago attention was first called to the fact that leaf impressions were to be found in a sandstone used for building purposes at Bridgeton, Cumberland Co., N. J. Specimens transmitted to Prof. Geo. H. Cook, then State Geologist, were by him referred to Dr. N. L. Britton, at that time his assistant on the State survey. A paper upon the subject was presented by Dr. Britton at the Montreal meeting of the A. A. A. S., in 1882, entitled "On a Post Tertiary Deposit Containing Impressions of Leaves, in Cumberland County, New Jersey."[1] Subsequently he embodied the result of his investigations in a paper read before the N. Y. Academy of Science, Nov. 24, 1884, under the title of "The Geological Age of the Pre-Glacial Drift."[2] During the year 1884, and a year or so subsequently, Messrs. J. B. Marcou and Frank Burns made further collections and the specimens were submitted to Prof. Leo Lesquereux for determination. They were numbered and some of them briefly described and provisionally named in the Proceedings of the U. S. Natural Museum.[3] Dr. John I. Northrop, of Columbia College, next took hold of the matter. Thus far the specimens had been too poor for accurate

[1] Proc. A. A. A. S. xxxi, 357-359.
[2] Trans. N. Y. Acad. Sci., iv, 31-33.
[3] Proc. U. S. Nat. Mus., x, 21-46 and xi, 11-42.

study or comparison. Dr. Northrop spent some time in 1889 collecting and succeeded in obtaining a fine suite of specimens and was invited to publish his conclusions as a bulletin of the U. S. Geological Survey. Many of the figures had been drawn and a few of the descriptions completed, when a sudden accident terminated his life, June 26, 1891, and I was subsequently requested to take up the work where he had left it and to carry it through to completion. It is now practically in shape for publication.

Some twenty-five genera are figured and described, representing a flora almost identical with that of to-day a few hundred miles farther south. Nearly every genus is a living one, as are also a majority of the species.

The medium in which they occur—a coarse, more or less friable sandstone—is a poor one for the preservation of fine veining or serrations and scores of the specimens are worthless for this reason. Nevertheless the great abundance of the material is such that an excellent selection has been possible. So far as I am informed this is the only deposit of such remains known from the horizon of the Yellow Gravel. The following well known genera are represented: *Magnolia*, *Asimina*, *Diospyros*, *Æsculus*, *Nyssa*, *Viburnum*, *Liquidambar*, *Ilex*, *Morus*, *Leucothoë*, *Laurus*, *Persea*, *Amelanchier*, *Hicoria*, *Castanea*, *Ulmus*, *Planera* and *Ostrya*, besides several whose exact affinities are doubtful. Amongst the most abundant and interesting of these latter are a number of leguminous pods, apparently allied to the genera *Mesoneuron* or *Pongamia*, and a reed-like organism, referred provisionally to *Cyperites*. The following are some of the living species which have been satisfactorily identified: *Magnolia acuminata*, L., *Asimina triloba*, (L.) Don., *Diospyros Virginiana*, Willd., *Nyssa uniflora*, Walt., *Planera aquatica*, Gmel., *Ulmus Americana*, L., *Ilex opaca*, Ait., *Leucothoë racemosa*, DC., *Liquidambar styraciflua*, DC., *Persea Borbonia*,(L.) Spreng, etc.—practically the arborescent flora of our Virginia lowlands to-day. It probably represents one of the latest fossil floras of which we have any remains and it no doubt flourished just previous to the era of the glacial epoch. The leaves bear evidence of having been deposited in slowly running water, as they are frequently so matted together that they cannot be separated. Further investigation would be sure to yield rich results, as the material is both abundant and readily obtained.

[The paper was illustrated by drawings and specimens.]

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EXHIBITION OF GUELPH FOSSILS FOUND IN ROCHESTER, N. Y. By ALBERT L. AREY, Rochester, N. Y.

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CERRO VIEJO AND ITS CONES OF VOLCANIC EJECTA AND EXTENSION IN NICARAGUA. By JOHN CRAWFORD, Government Geologist, Léon, Nicaragua.

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THE MATHEMATICS OF MOUNTAIN SCULPTURE. By VERPLANCK COLVIN, Supt. New York State Land and Adirondack Survey, Albany, N. Y.

RECENT GEOLOGICAL EXPLORATIONS IN MEXICO. By Prof. ROBERT T. HILL, Austin, Texas.

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THE VOLCANIC CRATERS OF THE UNITED STATES. By Prof. ROBERT T. HILL, Austin, Texas. [To be printed in Harper's Magazine.]

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THE HOMOTAXIC RELATIONS OF THE NORTH AMERICAN LOWER CRETACEOUS. By ROBERT T. HILL, Austin, Texas.

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THE AMERICAN MASTODON IN FLORIDA. By Dr. JOHN KOST, Adrian, Mich.

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THE MINING, METALLURGICAL, GEOLOGICAL, AND MINERALOGICAL EXHIBITS TO BE SHOWN AT THE WORLD'S COLUMBIAN EXPOSTION. By GEORGE F. KUNZ, Hoboken, N. J.

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PLEISTOCENE GEOGRAPHY. By W J McGEE, U. S. Geological Survey, Washington, D. C.

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DISTRIBUTION OF THE LAFAYETTE FORMATION. By W J McGEE, U. S. Geological Survey, Washington, D. C.

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ADDRESS

BY

# SIMON HENRY GAGE,

VICE PRESIDENT, SECTION F.

## *THE COMPARATIVE PHYSIOLOGY OF RESPIRATION.*

AMONG the very first of the physiological acts observed were those of respiration. The regular movements of breathing, from the first feeble efforts of the new-born babe until the sigh in the the last breath of the dying—after which is silence, cold, and dissolution—have commanded the attention and claimed the interest of every one, the thoughtful and the thoughtless alike. And one comes to feel that in some mysterious way "the breath is the life." But in what way does breathing subserve life or render it possible? Aristotle and the naturalists of the olden time supposed that it was to cool the blood that the air was taken into the lungs, and, as they supposed, also into the arteries. With the limited knowledge of anatomy in those early days, and the fact that after death the arteries are wholly or almost wholly devoid of blood, while the veins are filled with it, what could be more natural than to suppose that the arteries were vessels for the cooling air? If one supposes that he has entirely outgrown this view of Aristotle, let him think for a moment how he would express the fact that an individual is descended from the Puritans, for example. In expressing it even the physiologist could hardly bring himself to say other than "he has the blood of the Puritans in his *veins*." Would he ever say "he has the blood of the Puritans in his *arteries?*"

As observation increased, the cold-blooded animals were more carefully studied and found to possess also a respiration; they certainly do not need it to cool the blood. Then there are the insects and the other myriads of living forms that teem in the oceans, lakes, rivers and even in the wayside pools. Do these, too, have a breath? And the plants on the land and in the water, is the air vital to them? Aristotle and the older naturalists could not answer these questions. To them, on the respiratory side at least, all life was not in any sense the same.

It was not till chemistry and physics were considerably developed, not until the air-pump, the balance and the burette were perfected that it was possible to give more than a tentative answer. Not until the microscope could increase the range of the eye into the fields of the infinitely little, was it possible to form even an approximately correct conception. The first glimmering of the real significance of respiration for all living things was in the observation that the air which would not support a flame, although it might be breathed, could not support life. That is, there must be something in the transparent air that feeds the flame and becomes the breath of life, the real *pabulum vitæ*, the merely mechanical action of the air not being sufficient.

Since the experiments on insects and other animals with the air-pump, by Boyle (1670) by Bernuilli on subjecting fishes to water out of which all the air had been boiled, and those of Mayow (1674), it became more and more evident that respiration was not confined to the higher forms, but was a universal fact in the organic world. Then came the most fruitful discoveries of all, made by the immortal Priestley (1775–6), viz., that the air is not an element but composed of two constituents: Nitrogen, which is inert in respiration, and Oxygen, which is the real vital substance of the air, the substance which supports the flame of the burning candle and the life of the animal as well.

What would seem more simple at this stage of knowledge than that the parallel between the burning candle and the living organism should be thought to represent truly the real conditions? that as the burning candle consumes the oxygen and gives out carbon dioxide, so the living thing breathes in oxygen and in place of that consumed gives out carbon dioxide. And as in each case heat is produced, what would be more natural than to look upon respiration as a simple combustion? This was the generalization of Lavoisier (1780–1789). As he saw it, the oxygen entered the lungs, reached the blood and burned the carbonaceous waste there found and was immediately given out in connection with the carbon with which it had united; and as the gas given off in a burning candle makes clear lime water turbid, so the breath produces a like turbidity.

But here, as in many of the processes of nature, the end products or acts were alone apparent, and while the fundamental idea is probably true that respiration is, in its essential process, a kind of combustion or oxidation, yet the seat of this action is not the lungs or blood. If the myriads of microscopic forms are considered, these have no lungs, no blood, and many of them even no organs,—they are, as has been well said,—organless organisms; and yet every investigation since the time of Vinci and Von Helmont, Boyle and Mayow have rendered it more and more certain that every living thing must be supplied with the vital air or oxygen and that this is in some way deteriorated by use; and the nearer investigation approaches to the real life stuff or protoplasm, it alone is found to be the true breather, the true respirer. And further, as was shown long ago by Spallanzani (1803–1807), if one of the higher animals, as a frog, is decapitated and some of its muscle or other tissue exposed in a moist place, it will continue to take up oxygen and give out carbon dioxide, thus apparently showing that the tissues of the highly organized frog, may, under favorable conditions, absorb oxygen directly from the surrounding medium, and return to it directly, the waste carbon dioxide. This proves conclusively that it is the living substance which breathes, and that the elaborate machinery of lungs, heart and blood-vessels is only to make sure that the living matter, far removed from the external air, shall not be suffocated. Still more strange, it has been found that, if some of the living tissue is placed in an atmosphere of hydrogen or nitrogen entirely devoid of oxygen, it will perform its vital functions for a while, and although no oxygen can be obtained, it will give off carbon dioxide as in the ordinary air. If it is asked, "how can these things be?" the answer is apparently plain and direct. Not as the oxygen unites directly with the carbon in the burning candle, does it act in the living substance. The oxidations are not direct in living matter, as in the candle; but the living matter first takes the oxygen and makes it an integral part of itself, as it does the carbon and nitrogen and other elements; and finally when energy is to be liberated, the oxidation occurs, and the carbon dioxide appears as a waste product.

The oxygen that is breathed to-day, like the carbon or the nitrogen that is eaten, may be stored away and represent only so much potential energy to be used at some future time in mental or physical action.

So far only living animal substance has been discussed. If plants are considered, what can be said of their relations to the air? The answer was given in part by Priestley (1771) who found that air which had been vitiated by animal respiration became pure and respirable again by the action of green plants. He thus discovered the harmonizing and mutual action of animals and plants upon the atmosphere; and there is no more beautiful harmony in nature. Animals use the oxygen of the air and give to it carbon dioxide which soon renders it unfit for respiration; but the green plants take the carbon dioxide, retain the carbon as food and return the oxygen to the air as a waste product. This is as thoroughly established as any fact in plant physiology; and yet in his work Priestley had some which he called "bad experiments;" for instead of the plants giving out oxygen and purifying the air, they sometimes gave off carbon dioxide, and rendered it more impure after the manner of an animal. What investigator cannot sympathize with Priestley when he calls these "bad experiments?" They appeared so rudely to put discord into his discovered harmony of nature. But nature is infinitely greater than man dreams. The "bad experiments" were among the most fruitful in the history of scientific discovery. Ingenhausz (1787) followed them up, carefully observing all the conditions, and found that it was only in daylight that green plants gave out oxygen; in darkness or insufficient light they conducted themselves like animals, taking up oxygen and giving out carbon dioxide. Finally it was proved by Saussure (1804) and others that both for green plants, and those without green like the mushrooms oxygen is as necessary for life as for animals. It thus became evident that this use of oxygen and excretion of carbon dioxide was a property of living matter, and that the very energy which in the green plant set free the oxygen of the carbon dioxide was derived from oxidations comparable with those giving rise to energy in animals. Further that the purification of the air by green plants in light is a separate function—a *chlorophyll function*, as it has been happily termed by Bernard—and resembles somewhat digestion in animals, the oxygen being discarded as a waste product. Indeed so powerful is the effort made to obtain oxygen for the life processes by some of the lowest plants—the so-called organized ferments,—that some of the most useful and some of the most deleterious products are due to their respiratory activity. In alcoholic fermentation, as clearly pointed out by Pasteur and Bernard, the living ferment is removed from all sources of free oxygen and in the efforts of the ferment for respiration the molecules of the sugar are decomposed or rearranged and a certain amount of oxygen set free; and this oxygen supplies the respiratory needs of the ferment.

It has been found that the motile power of some bacteria like *Bacterium termo, e. g.*, depends on the presence of free oxygen in the liquid containing them. When this is absent they become quiescent. This fact has been utilized by Engelmann and others in the study of the evolution of oxygen by green and other colored water plants. The bacteria serve as the most delicate imaginable oxygen test, so that when the minutest green plant is illuminated by sufficient daylight, the previously quiescent bacteria move with great vigor and surround it in swarms. Out of the range of the plant the bacteria are still or move very slowly as if to conserve the minute energy-developing substance they have in store until it can be used to the best advantage.

May we not now approach the problem directly and answer, for the whole organic, living world, the question, "what is respiration?" by saying *it is the taking up of oxygen and giving out of carbon dioxide by living matter.* This is the universal and essential fact with all living things whether they are animals or plants, whether they live in the water or on land. But the ways by which this fundamental life process is made possible, the mechanisms employed to bring the oxygen in contact with the living matter and to remove the carbon dioxide from it are almost as varied as the groups of animals; each group seems to have worked out the problem in accordance with its special needs. It is possible, however, in tracing out these complex and varied methods and mechanisms, to recognize two principal ones,—*The Direct and the Indirect.*

In the first, there is the direct assumption of oxygen from the surrounding medium, and the excretion of carbon dioxide directly into it. The best examples of this are presented by unicellular forms like the amœba where the living substance is small in amount and everywhere laved by the respiratory medium. But as higher and higher forms were destined to appear, evidently the minute, organless amœba could not in itself realize the great aim toward which Nature was moving. There must be an aggregation of amœbas, some of them serving for one purpose and some for another. Like human society, as civilization advances, each individual does fewer things, becomes in some ways less independent, but in a narrow sphere acquires a marvelous proficiency. Or, to use the technical language of science: *In order to advance there must be aggregation of mass, differentiation of structure and specialization of function.* Evidently, however, if there is an aggregation of mass, some of the mass is liable to be so far removed from the supply of oxygen and the space into which carbon dioxide can be eliminated that it is liable to be starved for the one and poisoned by the other. Nature adopted two simple ways to obviate this: First, to form its aggregated masses into a kind of network or sponge with intervening channels through which a constant stream of fresh water may be made to circulate, so that each individual cell of the mass could take its oxygen and eliminate its carbon dioxide with the same directness as its simple prototype, the amœba.

But in the course of evolution forms appeared with aërial respiration; and the insects, among these, solved the mechanical difficulty of respiration by a most marvelous system of air tubes or tracheæ extending from the free surface, and therefore from the surrounding air, to every organ and tissue. By means of this intricate network air is carried and supplied almost directly to every particle of living matter. The respiration is not quite direct with the insects, however, for the oxygen and carbon dioxide must pass through the membranous wall of the air tube before reaching or leaving the living substance.

In the next and final step, the step taken by the highest forms, the living material is massed, giving rise not only to animals of moderate size, but to the huge creatures that swim in the seas like the whale or walk the earth like the elephant. With all of these the step in the differentiation of the respiratory mechanism consists in the great perfection of lungs or gills, and in the addition of a complicated circulatory system with a respiratory blood, one of the main purposes being, as the name indicates, to subserve in respiration by carrying to each individual cell in the most remote and hidden part of the body the vital air, and in the same journey removing the poisonous carbon dioxide.

This has been called *Indirect Respiration*, because the living matter of the body does not take its oxygen directly either from air or water, but is supplied by a middle man, so to speak.

The complicated movements by which water is forced over the gills, or by which the lungs are filled and emptied, and the great currents of blood are maintained, that is, the striking and easily observed phenomena of respiration are thus seen to be only superficial and accessory; they only serve as agents by which the real and the essential processes that go on in silence and obscurity are made possible.

So far I have attempted to give a brief résumé of the views on respiration that have been slowly and laboriously evolved by many generations of physiologists, each adding some new fact or correcting some misconception; and I trust that this brief sketch has recalled to your minds the salient facts in our knowledge of respiration, and that it will give a just perspective, and enable me, if I may be permitted, to describe briefly what I believe to be my own contribution to the ever-accumulating knowledge of this subject.

In 1876–1877, Professor Wilder, who may be said to have inherited his interest in the ganoid fishes directly from his friend and teacher, Agassiz, who first recognized and named the group, was studying the respiration of the forms *Amia* and *Lepidosteus*, common in the great lakes and the western rivers. As his assistant it was my privilege to aid in the experiments, and thus to acquire the spirit and methods of research in the most favorable way, by following an investigation by a master from its beginning to its close. The results of that inquiry were reported to this section in 1877, and formed a part of the Proceedings of the Association for that year. From that time till the present the problems of respiration in the living world have had an ever increasing fascination for me and no opportunity has been lost to investigate the subject. The interest was greatly increased by the discovery that a reptile—the soft-shelled turtle—did not conform to the generalizations in all the treatises and compendiums of zoölogy, which state with the greatest definiteness that all reptiles, without exception, are purely air breathing, and throughout their whole life obtain oxygen from the air and never from the water. The American soft-shelled turtles, *Amyda* and *Aspidonectes*, at least, do not conform to this generalization, but on the contrary naturally and regularly breathe in the water like a fish as well as in the air like an ordinary reptile, bird, or mammal.

In carrying on the investigation of the respiration of the turtle there appeared for solution the general problem, which briefly stated is as follows:—In case an animal breathes both in the air and in the water, or more accurately, has both an aërial and an aquatic respiration like the Ganoid fishes *Amia* and *Lepidosteus*, like the soft-shelled turtles, the tadpoles and many other forms, what part of the respiratory process is subserved by the aqueous and what by the aërial portion of the apparatus? So far as I am aware this problem had not been previously considered. It was apparently assumed that there were in these fortunate animals two independent mechanisms, both doing precisely the same kind of work, that is, each serving to supply the blood with oxygen and to relieve it of carbon dioxide as though the other were absent. That was a natural inference, for with many forms the respiration is wholly aquatic, all the oxygen employed being taken from the water and all the carbon dioxide excreted into it. On the other hand in the exclusively air breathing animals, as birds and mammals, the respiration is exclusively aërial.

This natural supposition was followed in the first investigations on the respiration of the soft-shelled turtles, and while it was proved with incontestable certainty that they take oxygen from the water like an ordinary fish, that is, have a true aquatic respiration in addition to their aërial respiration, there was altogether too much arbon dioxide in the water to be accounted for by the oxygen taken from it. Furthermore, upon analyzing the air from the lungs urtle that had been submerged sometime, the oxygen had nearly all disappeared and but very little carbon dioxide was found in its place, whereas by analogy with human respiration for example, a quantity of carbon dioxide nearly as great as that of the oxygen which had disappeared should have been returned to the lungs. Likewise in Professor Wilder's experiments with *Amia*, to use his own words: "Rather more than one per cent. of carbon dioxide is found in the normal breath of the *Amia;* but much more of the oxygen has disappeared than can be accounted for by the amount of carbon dioxide." Everything thus appeared anomalous in this mixed respiration, and instead of a clear, consistent and intelligible understanding of it there seemed only confusion and ambiguity. Truly these seemed like "bad experiments."

It became perfectly evident that the first step necessary in clearing the obscurity was to separate completely the two respiratory processes, to see exactly the contribution of each mechanism to the total respiration. But this was no easy thing to do. In the first place the animal must be confined in a somewhat narrow space in order that air and water which are known to have been affected by its respiration may be tested to show the changes produced in it by the respiratory process; in the second place the water has so great a dissolving power upon carbon dioxide that even if it were breathed out into the air it would be liable to be absorbed by the water; then some means must be devised to prevent the escape of the gases from the water as their tension becomes changed; and, finally, as the animal in the water must be able to reach the air, a diaphragm must be devised which would prevent the passage of gases between the air and the water, and at the same time offer no hindrance to the animal in projecting its head above the water. As a liquid diaphragm must be used it occurred to me that some oil would serve the purpose; but the oil must be of a peculiar nature, it must not allow any gases to pass from air to water or the reverse, it must not be in the least harmful or irritating to the animal under experimentation and, finally, it must itself add nothing to either air or water. Olive oil was thought of and later the liquid paraffins. The latter were found practically impervious to oxygen and fulfilled all the other requirements, but unfortunately they absorb a considerable quantity of carbon dioxide. Pure olive oil was finally settled upon as furnishing the nearest approximation to the perfect diaphragm sought.[1]

The composition of the air being known, and a careful determination of the dissolved gases in the water having being made, the animal was introduced into the jar and the water covered with a layer of olive oil from ten to fifteen millimeters thick. The top of the jar was then vaselined, and a piece of plate glass pressed down upon it thus sealing it hermetically. Two tubes penetrate this plate-glass cover, one connecting with the overlying air chamber and the other extending into the water nearly to the bottom of the jar. As the water and air were limited in quantity the shorter the time in which the animal remained in the jar the more nearly normal would be the respiratory changes; the experiments were therefore continued only so long—one or two hours—as was found necessary to produce sufficient change in the air and the dissolved gases of the water to render the analyses unmistakable.

Proceeding with the method just described, the results given in the following table were obtained:

[1]See Wm. Thörner on the use of olive oil for the prevention of the absorption of carbon dioxide. Repertorium der analytischen Chemie, 1885, pp. 15–17.

*Table of mixed Respiration, showing the number of cubic centimeters of oxygen removed from air and water, and the amount of carbon dioxide added to the air and the water per hour and kilogram.*

| | OXYGEN | | CARBON DIOXIDE | |
|---|---|---|---|---|
| | FROM AIR | FROM WATER | TO AIR | TO WATER |
| Ganoid Fish (*Amia calva*) | 65 | 10 | 22 | 53 |
| Tadpoles (*Larval Batrachia*) | 70 | 5 | 24 | 51 |
| Soft-shelled Turtle (*Amyda mutica*) | 31 | 8 | 10 | 29 |
| Bull Frog (*Rana catesbiana*) | 188 | 4 | 110 | 77 |

The oxygen from both the water and the air and the carbon dioxide in the air, were determined with exactness in all the experiments; but owing to the failure of some steps in the titration for the carbon dioxide in the water, the figures given for the Amia and the soft-shelled turtle are the calculated results, assuming that the respiratory quotient is one, as that is the relation found by analysis in the other cases. This table will be greatly extended when the results of the investigation now in progress are published.

It requires but a glance at the figures in this table to see that the aërial differs markedly from the aquatic part of the respiration. Even in the frog, in which the skin forms the only aquatic respiratory organ, the tendency is marked. The law appears to be unmistakably this, viz., *that in combined aquatic and aërial respiration, the aërial part is mainly for the supply of oxygen and the aquatic part largely for the excretion of carbon dioxide.* This law which I stated in 1886 has been confirmed by the repetition of old experiments and by many new ones made during the present summer. It is also confirmed by the experiments made on Lepidosteus in a different way by Dr. E. L. Mark, and published in 1890. I therefore feel confident that this is the expression of a general physiological law in nature.

From the standpoint of evolution we must suppose that all forms originated from aquatic ancestors, whose only source of oxygen was that dissolved in the water. As the water is everywhere covered with the limitless supply of oxygen in the air—there being 209 parts of oxygen in 1000 parts of air as contrasted with the 6 parts of oxygen dissolved in 1000 parts of water—it is not difficult to conceive that in the infinite years the animals found by necessity and experience that the needed oxygen was more abundant in the overlying air, and that some at least would try more and more to make use of it. And as any thin membrane with a plentiful blood supply may serve as a respiratory organ to furnish the blood with oxygen, it is not impossible to suppose that such a membrane, as in the throat, could modify itself little by little with ever increasing efficiency; and that one part might become especially folded to form a gill and another might become saccular or lung-like to contain air. While I am no believer in the purely mechanical physiology which sees no need of more than physics and chemistry to render possible and explain all the phenomena of life, yet it is patent to every one that, although vital energy is something above and beyond the energies of physics and chemistry, still it makes use of these; and certainly dead matter forms the material from which living is built. So, given a living thing, it, in most cases, moves along lines of least, rather than of greatest resistance; therefore, if a practically limitless supply of oxygen may be obtained from the air and only a limited amount from the water, if any thing that might serve as a lung is present, most naturally the animal will take the oxygen from the air where it is in greater abundance and more easily obtained. On the other hand, carbon dioxide is so soluble in water that practically an unlimited amount may be excreted into it; and as it is apparently somewhat easier, other things being equal, for it to pass from the liquid blood to the water than to the air, it seems likewise natural that the gills should serve largely for the excretion of the carbon dioxide into the water. This is the actual condition before us in these, and I believe in all other cases, of mixed or of combined aërial and aquatic respiration. And I believe, as stated above, the law in respiration is, that whereever both water and air are used with corresponding respiratory organs *the aërial part of the respiration is mainly for the supply of oxygen, and the aquatic part largely for the getting rid of carbon dioxide.*

It is not difficult to see in an actual case like that of the Ganoid Fishes (*Amia* and *Lepidosteus*) the logical steps in its evolution, by which this most favorable condition has been reached; a condition rendering these fishes capable of living in waters of almost all degrees of purity, and thus giving them a great advantage in the struggle for existence. But what can be said of the soft-shelled turtles, animals belonging to a group (Reptilia) in which purely aërial respiration is almost exclusively the rule? Standing alone, this might be exceedingly difficult or impossible of explanation. The Batrachia (frogs, toads, salamanders, etc.), all have gills in their early or larval stage, and most of them develop in the water, and are in the beginning purely aquatic animals. The adults must therefore, in most cases, repair to the water at the spawning season, and frequently in laying the eggs they must remain under the water for considerable intervals. Being under the water and the need of oxygen becoming pressing, there seems to be, by a sort of organic memory, a revival of the knowledge of the way in which respiration was accomplished, when as larvæ their natural element was water, and they may take water into the mouth and throat. This may be done by as highly a specialized and purely aërial form as the little brown tree-frog (*Hyla pickeringii*) or the yellow spotted salamander (*Amblystoma punctatum*). Another very interesting form, the vermilion-spotted newt (*Diemyctylus*), after two or three years of purely aërial existence, goes to the water on reaching maturity, and remains there the rest of its life, regularly breathing both by its lungs and by taking water into its mouth. A still more striking example is given by Professor Cope. The young Siren almost entirely loses its gills, and later regains them, becoming again almost completely aquatic in its habits as in the larval stage.

With these examples, which may be seen by any one each recurring year, is it impossible or difficult to conceive that, in the struggle for existence, the soft-shelled turtle found the scarcity of food, the dangers and hardships on the land, greater than those in the water? On remaining constantly in the water, and advantageously submerged for most of the time, it gradually re-acquired the power of making use of its pharyngeal membrane for obtaining oxygen from the water and excreting carbon dioxide into it as had its remote ancestors. And, further, is it not intelligible that with capacious lungs, which it can fill at intervals with air containing so large a supply of oxygen that it, like the other double or mixed breathers, should use its lungs to supply most of the oxygen and its throat to get rid of much of the carbon dioxide?

Indeed, it seems to me that if the evolution doctrine is a true expression of the mode of creation, then development may be in any direction that proves advantageous to an organism, even if the development is a re-acquirement of long discarded structures and functions.

In closing may I be permitted to say to the older biologists,—to those familiar with the encouragements and inspirations that come with original investigation, that I trust they will pardon what to them is unnecessary personality or excess of detail in this address, for the sake of the younger ones among us, to whom the up-hill road of research is less familiar. Judging from my own experience in listening to similar addresses by my honored predecessors, it is helpful to know, when one is beginning, something of the *dead work*, the difficulties and discouragements as well as the triumphs in the Advancement of Science.

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# PAPERS READ.

A PRELIMINARY ACCOUNT OF THE BRAIN OF DIEMYCTYLUS VIRIDESCENS, BASED UPON SECTIONS MADE THROUGH THE ENTIRE HEAD. By SUSANNA PHELPS GAGE, Ithaca, N. Y.

[ABSTRACT.]

I. AN effort has been made to determine whether the remarkable changes in appearance, physiological function and histological structure, which occur at certain crises in the life history of *Diemyctylus viridescens* are accompanied by corresponding changes in the structure or mass of the brain.

II. Thus far in the investigation the facts found negative this idea, as it appears that within a few days of hatching, the main differentiations of the brain have been laid down.

III. In young larva the cells are very large but the diminution to the adult size seems gradual, while in general appearance the brain of the young is shorter and thicker than the adult, and the commissures seen in reconstructed mesal sections are less developed.

The remarkable muscular correlation, and the well developed condition of the eye and ear, in the young larvæ probably corresponds to the early development of the brain.

IV. Attention is called to the coalescing of the optic lobes, the remarkable lateral projection of the infundibulum or torus; the changes in the hypophysis; the condition of the pineal eye; the relations of the plexuses to the cavities and the endyma; and the relation of the intermaxillary gland to the brain.

[This paper was illustrated by a model and diagram.]

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ON THE DIGESTIVE TRACT OF SOME NORTH AMERICAN GANOIDS. By G. S. HOPKINS, Ithaca, N. Y.

[ABSTRACT.]

*A*. SEVERAL organs (air-bladder, nasal cavity, gall-bladder and its duct) of *Amia calva* have been found to be lined by a ciliated epithelium.

*B*. In the common sturgeon either the œsophagus possesses glands or else the air-bladder opens into the stomach.

*C*. Nearly the whole of the ental surface of the stomach of sturgeon is lined by ciliated cylindrical cells.

*D.* Ciliated cells are also found in the stomach of Polyodon and Scaphorhynchops.

*E.* In the rectum of Amia, just caudad of the spiral valve, there is a small area containing ciliated cells.

[This paper will be printed in Proceed. of Amer. Micros. Society.]

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THE "MAXILLARY TENTACLES" OF PRONUBA. By JOHN B. SMITH, Sc.D., New Brunswick, N. J.

[ABSTRACT.]

IN his excellent studies on the species of *Pronuba*, Dr. C. V. Riley has called special attention to the peculiarities of the mouth structure, and particularly to the development of a so-called "maxillary tentacle." The figures given of this structure in the various species are excellent, and aroused a suspicion in my mind that, while they were really special developments in one sense, so far as we now know unique in Lepidoptera, yet that there were homologous structures elsewhere in other orders. That is to say, there is really no new organ or process, but a mere adaptation or development of a known maxillary sclerite, which is paralleled by similar developments of the same sclerite in other groups. To the courtesy of Dr. Riley I owe a supply of specimens for examination, and from a careful study of these, I have concluded that the so-called tentacle is really an extension of the palpifer or palpus bearer. Of all the Lepidoptera known to me, *Pronuba* has the maxillary sclerites best developed. Dr. Riley has called attention to the fact that the two halves of the spiral tongue are not united, as is usual in the higher Lepidoptera to form a tube, and I find that when the two maxillæ are dissected off, the structure bears a remarkable resemblance to that found in the coleopterous genus *Nemognatha*; the lacinia being lacking while some of the other sclerites are better marked. A comparison of the figures of *Nemognatha* and of *Pronuba*, male, will at once, emphasize this similarity. In the male *Pronuba* the "maxillary tentacle" is not developed; but if we examine the large sclerite at the base of the palpus, which is palpifer without question, we see, evidently, the structure whose prolongation and specialization form the "tentacle." This special development of the palpifer is not unique in *Pronuba*; but is of common occurrence in the piercing *Diptera*.

In a paper published by me in the Transactions Amer. Ent. Society, XVII, 1890, I showed the modifications of this structure in the *Diptera*; but I was at that time unable to decide whether I had to do with a palpifer or with a stipes. In the Hemiptera the same sclerite is also developed into a piercing organ although the maxillary palpi themselves are rudimentary. It may be objected that these are rigid, chitinous processes while in *Pronuba* the process is flexible and set with numerous tactile or specialized spines. This kind of change is not unusual in insects, and precisely the same difference appears between the rigid chitinous ligula of the piercing *Diptera* and the flexible sensitive ligula of the bees. In

the structure of the galea, yet more marked changes occur; but in the *Panorpidæ* of the order Hymenoptera we have a development of the palpifer which is not rigid, but is membraneous though not flexible, and is set with hair which in part at least is tactile in function. In the same family of *Panorpidæ* we have a most remarkable example of the elongation of mouth parts. The lacinia is small, but obvious; the subgalea is elongated from each side forming lobes; each joint of the galea is elongated between these lobes and finally the palpifer is a flattened elongated process from the base of which the palpus arises. The conclusion, after an examination of these structures is irresistible. The flexible process in *Pronuba* is an extension of the palpifer, homologous with the rigid structures in the *Hemiptera* and piercing *Diptera* and with the more membraneous structure in the *Panorpidæ*. It is a special development only in the sense that it is adapted for a special duty, and in the same sense that the ligula in *Tabanus* and *Apis* are each special developments for the advantage of those insects.

[This paper will be printed in Insect Life.]

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THE DESCENT OF THE LEPIDOPTERA. AN APPLICATION OF THE THEORY OF NATURAL SELECTION TO TAXONOMY. By Prof. JOHN HENRY COMSTOCK, Cornell University, Ithaca, N. Y.

[ABSTRACT.]

THERE is indicated in this paper a method of applying the theory of natural selection to taxonomy somewhat more fully than seems to have been done before.

The method consists in beginning with the study of a single organ possessed by the group of organisms to be classified. The variations in form of this organ are observed; the function of the organ is studied; and an effort is made to trace out the phylogenetic development of the organ, keeping constantly in mind the relation of the changes in form of the organ to its function. In other words, the record of the action of natural selection upon the group of organisms is read as it is recorded in a single organ. This gives data for a provisional classification of the group. Then another organ is selected and its history worked up in the same way. Then the results obtained in the two investigations are compared; and where they differ there is indicated the need of renewed study. For if rightly understood the different records of the action of natural selection will not contradict each other. The investigation is continued by the study of other organs and a correlating of results obtained until a consistent history of the group has been worked out.

This method differs from that commonly employed, in being a constant effort to determine the action of natural selection in the modification of the form of organisms, in order to better adapt their parts to perform

their functions. By the old method a search is made for characters by which a group can be divided and subdivided with but little regard to the meaning of these characters. In fact we rarely see in purely taxonomic works any reference to the functional significance of the characters used.

As illustrating the proposed method of study, the structure and function of the wings of the Lepidoptera are discussed and conclusions are drawn from this study regarding the phylogeny of the order.

It is shown that as a rule those forms in which the wings are broad and furnished with many veins are more generalized than those having narrow wings furnished with fewer veins.

But it is also shown that in some cases broad-winged forms have evidently been developed from forms with narrower wings, as in the Saturniidæ, and, probably, in butterflies; and an explanation of this apparent retrograde development is offered.

It is also shown that the action of natural selection has tended towards a uniting of the two wings of each side during flight in order to insure their synchronous action. In the majority of the existing families this is accomplished by means of a frenulum. But in some families the frenulum has been superseded by an overlapping of the wings and a development of a forward projecting shoulder at the base of the costal edge of the hind wings, which render a frenulum unnecessary.

It is also shown that in the case of two families, the Hepialidæ and the Micropterygidæ, the wings are united in an entirely different manner. Here, instead of a frenulum born by the hind wing, there has been developed a backward projecting lobe near the base of the inner margin of the fore wing. This lobe passes beneath the hind wing; and thus the costal edge of the hind wing is held between this lobe and the inner margin of the fore wing which overlies the hind wing.

For this lobe of the fore wing which has not been observed in the Lepidoptera heretofore the name *jugum* is proposed.

From this study the conclusion is drawn that in the primitive Lepidoptera the wings of each side were not fastened together during flight; that later in certain forms a frenulum was developed; while in other forms a jugum arose. We have therefore in existing Lepidoptera representatives of two distinct lines of development. And it is proposed, therefore, to divide the order into two sub-orders; one to be named the *Frenatæ* and the other the *Jugatæ*.

The relative reduction of the different areas of the hind wings in different families is then discussed. And it is shown that an entirely different course is followed in the Jugatæ from that which takes place in the Frenatæ, thus confirming the conclusion drawn as to the naturalness of the proposed division of the order into two sub-orders.

Reference is also made to the taxonomic value of the clothing of the wings of the Lepidoptera, and to a discovery made by Prof. V. L. Kellogg, while working in my Laboratory, that in certain important respects the clothing of the wings of the Jugatæ more closely resembles that of the

Caddice-flies than that of the Frenatæ. It is also pointed out that at least many of the Caddice-flies resemble the Jugatæ in the possession of a jugum.

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AN INTERESTING CASE OF PARASITISM. By Prof. ALBERT H. TUTTLE, University of Virginia, Charlottesville, Va.

[ABSTRACT.]

THIS paper reports the discovery of a nematoid living as a parasite in the venom organ of the common rattlesnake (*Crotalus horridus L.*). The venom (which was removed for experimental purposes) was found to contain a large number of immature worms, which continued to live in the fresh venom during the time the latter was under examination (nearly two weeks), and several disrupted females containing larvæ, showing the species, which is not yet determined, to be viviparous. An account will be published in the American Naturalist.

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ON THE ADULT CESTODES OF CATTLE AND SHEEP. By Dr. C. W. STILES, U. S. Dept. Agric., Washington, D. C.

[ABSTRACT.]

AN account was given of recent investigations by the Bureau of Animal Industry of the microscopic anatomy of cestodes found in cattle and sheep. Specimens (microscopic slides) of various species were exhibited. The relation of *T. Giardi* to Blanchard's new genus *Moniezia* was discussed. Two forms from Africa were exhibited. Also the original specimens of *Taenia denticulata* and *T. expansa* Rudolphi, 1810. The generic and specific characters which followed are based upon internal anatomy (position and number of testicles, uteri, penis, vagina, etc.).

[This paper will be printed in Report of U. S. Dept. Agric.]

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THE PRODUCTION OF IMMUNITY IN GUINEA PIGS FROM HOG CHOLERA BY THE USE OF BLOOD SERUM FROM IMMUNIZED ANIMALS. By Dr. E. A. DE SCHWEINITZ, Bur. Animal Ind., Dept. of Agr., Washington, D. C.

[ABSTRACT.]

THE paper gave an account of some experiments on the production of immunity in guinea pigs by the use of blood, and of curing them in the same way. It also gave the result of some observations which go to show the increase in the number of white blood corpuscles in guinea pigs while they are being immunized, and afterwards again when inoculated.

[This paper will be printed in Medical News, Phila.]

PRELIMINARY NOTE ON THE ANATOMY OF THE UKODELE BRAIN AS EXEMPLIFIED BY DESMOGNATHUS FUSCA. By PIERRE A. FISH, Ithaca, N. Y.

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THE ANIMAL PARASITES OF DOGS. By Prof. E. W. DORAN, Maryland Agricultural College, College Park, Md.

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THE INSECT FAUNA OF THE MISSISSIPPI BOTTOMS. By Prof. H. E. WEED, Agricultural College, Mississippi. [Paper will be printed in the Canadian Entomologist.]

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ON CARPHOXERA PTELEARIA, THE NEW HERBARIUM PEST. By Prof. C. V. RILEY, U. S. Department of Agriculture, Washington, D. C.

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BIOLOGICAL NOTES ON THE FAUNA OF COLD SPRING HARBOR. By Prof. C. W. HARGITT, Syracuse, N. Y.

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NOTES ON SOME FRESH-WATER MOLLUSKS. By Rev. W. M. Beauchamp, Baldwinsville, N. Y.

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ON TWO EMBRYO CHICKS IN A SINGLE BLASTODERM. By ROBERT W. MOODY, Fair Haven Heights, New Haven, Conn.

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HEREDITY OF ACQUIRED CHARACTERS. By Dr. MANLY MILES, Lansing, Mich.

THE remarkable progress of science for nearly half a century must be largely attributed to the general recognition and extended applications of the laws of evolution, and the conservation of energy.

In the biological departments of science, evolution has had a predominant influence in suggesting lines of investigation, and in the interpretation of results, while the significance of energy as a factor in all organic processes has not been as fully recognized.

In both vegetable and animal physiology there is a growing tendency to look upon the collocations of matter as incidents, or manifestations of the transformations of energy, and the changes taking place in vital activities are conveniently expressed by the general term *metabolism* that includes the dynamic as well as the material factors, which cannot be separately considered from the complexity of their intimate relations. Even in the processes of nutrition it appears that the demands for the material elements of tissue are limited, while the expenditures of energy in the constructive processes, and their collateral functions, are enormous.

It is not my purpose to attempt a general discussion of the conservation of energy as a factor in biological activities, but to call attention to some of the processes of nutrition with reference to their import as causes of variation, or the origin of new characters that may be made available through natural selection in the evolution of plants and animals.

The inheritance of acquired characters has been called in question by Weismann and positively denied by those who accept his theory of the continuity of the germ plasma as originally formulated, and all inheritable variations are assumed to be the result of fortuitous changes in the reproductive germs. The advocates of this theory confine their attention almost exclusively to gross morphological characters, which have been developed and fixed through an accumulation of numerous slight variations for many generations, and ask for direct proof of the complete transformation of these established characters, by changes in the habits of a single individual; while the abundant evidence of physiological or functional changes in nutritive processes, which must be considered as the necessary precursors and probable causes of morphological changes, is claimed to be inadmissible.

The processes of metabolism in the nutrition of plants and animals, as now interpreted by physiologists, furnish a rational explanation of the manner in which the reproductive cells may be influenced by functional adaptations of organisms to their environment, which are admitted to be causes of individual variations, and theories of heredity and evolution in which these physiological factors are not taken into consideration, cannot be accepted as a satisfactory solution of the problems presented.

Omitting subordinate details, which represent the separate links in the chain of events, the processes of nutrition may be summarized in general terms as follows: In plants the chemical elements and binary compounds on which they feed, are built up by successive steps of increasing complexity and instability into protoplasm, with a storing of the energy made use of in the constructive process, which is derived from the heat and light of the sun. The constructive processes are expressed by the term anabolism and the products of the different upward steps are called anastates.

Protoplasm, the most complex and unstable of organic substances, is the summit of the ascending steps of anabolism; and katabolism, which represents the succeeding downward steps of metabolism, then follows, and its products or katastates are starch, cellulose, proteids, etc., or what we recognize as the proximate constituents and tissues of plants.

The heat developed in the nutrition of plants is also a product of katabolism, and it represents the difference between the potential energy of the protoplasm and the potential energy of the other katastates formed from it. This is not, however, sufficient to enable the plants to maintain an independent temperature, as it is rapidly dissipated by radiation from the extended surface of the foliage, and a large amount is used in vaporizing the water exhaled by the leaves. An approximate quantitative estimate of the energy expended in exhalation was given in a paper read before section I last year, and published in the Popular Science Monthly for May.

From their greater complexity the more highly differentiated processes of nutrition in animals are not so readily traced, but the general course and results of metabolism, broadly stated, are essentially the same as obtain in plants. The food of animals consists of the proximate constituents of plants, or the katastates of plant metabolism; and, with the exception of oxygen introduced in the process of respiration, they are unable to assimilate the simpler elements on which plants feed.

The first demand of the animal economy is for energy to be used in the constructive processes, and this is derived exclusively from the stored energy of the organic substances of their food, through the destructive metabolism involved in the processes of digestion. The proteids, fats, and carbhydrates of the food of animals are not directly converted into animal proteids and fats, but the evidence indicates, as pointed out by Dr. Foster, that they are reduced almost to their original elements and then reconstructed through the agency of animal protoplasm. In no other way can the energy required in animal nutrition be obtained, and as an incident of the destructive metabolism of foods in the processes of digestion, the materials for the constructive process are provided for immediate use in a simpler form than that in which they were ingested.

In general terms we may then say that the anabolic processes of animal nutrition consist in utilizing the liberated energy in building these disintegrated food constituents into protoplasm, with a storing of the energy as an essential condition of its constitution; and the animal proteids and fats, and in fact the tissues generally are the katastates of its destructive metabolism that contain less potential energy than the protoplasm from which they are formed; the difference appearing as animal heat, which is supplemented by the destructive metabolism of the tissues involved in their functional activity, or what is popularly called the wear and tear of the system. As in plants protoplasm is the summit, or the highest phase of the anabolic activities, and tissue building must be looked upon as a result of its katabolic transformations.

In the higher animals the nutritive processes are more complex, and the number of upward and downward steps of metabolism is increased, through the elaboration of a common nutritive fluid, the blood; but the sum and final outcome of the anabolic and katabolic changes are essentially the same as in the simpler organisms. Energy is used and stored up in the anabolic, or constructive, processes and liberated again as animal heat in the "simultaneous and successive" katabolic processes which result in the formation of the various tissues.

Protoplasm is no longer looked upon as a substance of a definite chemical composition and constitution, as it must vary widely in its specific properties in the different species of plants and animals, and even in the different organs of the individual, and the varieties of protoplasm are therefore innumerable. In addition to these variations, arising from the characteristics of protoplasm in different species, and in their highly differentiated organs, the anastates representing the successive steps of its elaboration, and the katastates resulting from its destructive metabolism, in the same individual, must vary with the ever changing conditions of the environment, and the functional activity of every part of the organism. Individual variations from the prevailing type of the group, or family, are thus readily accounted for by a disturbance in the symmetrical balance of the metabolism of the different organs of the body, by prevailing habits, or changes in the environment and conditions of food supply.

In the phases of life from the embryo to the final decline of the bodily powers, there are changes in the relative predominance of anabolic and katabolic activities which we should not fail to notice. In Dr. Minot's interesting address at Indianapolis, "On Certain Phenomena of Growing Old," the sequence of mutations in metabolic activities in the life of the individual were clearly shown. The greater activity of the nutritive functions in youth, and their gradual decline to maturity and old age, were strikingly illustrated by an instructive series of statistical diagrams. It was also shown "that with the increasing development of the organism and its advance in age, we find an increase in the amount of protoplasm."

This apparently conflicts with the conception of protoplasm as the physical basis of life, and the most plausible inference from these facts, as suggested by Dr. Minot, was that "the development of protoplasm is the cause of the loss of power of growth," and that "protoplasm was the physical basis of advancing decrepitude."

A less obvious but more satisfactory explanation is furnished in the outline of the processes of nutrition already presented. It is evident that protoplasm is but a way station, as it were, in the development of tissues, and its destructive metabolism is an indispensable condition of growth and increase of organic substance. The greatest activity of the katabolic phases of metabolism take place in the embryo and youth, and they then keep pace with the anabolic or constructive processes of the organism, so that the protoplasm elaborated is used in tissue building as fast as it is formed.

When maturity is reached the demand for new materials in growth ceases, the wear and tear of the system is diminished, with less intense demands for the processes of repair. With this falling off in the requirements of the organism for katabolic products, including energy, anabolism predominates and protoplasm is allowed to accumulate in the different organs from the check to destructive metabolism arising from the general decline of vital activities.

The hypothesis, that the germ plasma or its representative reproductive granules are immortal and entirely independent of the body plasma, on which is based the assumption that acquired characters cannot be transmitted, appears to be in direct conflict with these physiological laws of nutrition. The protoplasm of the body presents, as we have seen, many differentiated varieties adapted to the specific function of each organ, and its katastates differ accordingly. The various glandular secretions, the products of nervous and muscular activities, the numerous excretory products, and even the germ cells, so far as their molecular structure is concerned, must be considered as katastates of the protean varieties of protoplasm. The so-called body plasma must then be looked upon as made up of many differentiated subdivisions in genetic relations with many katabolic products, all of which are correlated, through vital activities, to act in harmony to serve the entity we recognize as the individual. The differentiation of a germ plasma especially concerned in the function of reproduction must be accepted as a physiological factor of the first importance, but we are not warranted in assuming that it is exempt from the metabolic transformations that characterize other living substances.

Herbert Spencer defines life as "the continual adjustment of internal relations to external relations," and Dr. Foster expresses substantially the same conception in defining living substance as "not a thing or body of a particular chemical composition, but matter undergoing a series of changes." These definitions fairly represent our present knowledge of vital activities. Metabolism, with its "simultaneous and successive" phases of anabolic and katabolic transformations of matter and energy, is admitted to be an essential condition of life in all tissues and elements of the body. As living matter, the germ plasma must be continually undergoing metabolic changes in adjusting its internal relations to its external relations with the body plasma, and interchanges of matter and energy must be involved in its increase and growth.

These constant changes in the substance of the germ cells were not recognized in the original hypothesis of the continuity of the germ plasma. As formulated by Weismann "heredity is brought about by the transference from one generation to another of *a substance* with a definite chemical, and above all, molecular constitution," which he called germ plasma, and assumed that it possesses a "highly complex structure conferring upon it the power of developing into a complex organism," and heredity was further explained "by supposing that in each ontogeny a part of the specific germ plasma contained in the parent egg-cell is not used up in the construction of the body of the offspring, *but is preserved unchanged for the formation of the germ cells of the following generation.*" Again he says, "The germ plasma, or idioplasm of the germ cell (if this latter term is preferred), certainly possesses *an exceedingly complex minute structure, but it is nevertheless a substance of extreme stability, for it absorbs nourishment and grows enormously without the least change in its complex molecular structure.*"

It is difficult to understand how a living substance undergoing constant metabolic changes can be "a substance of extreme stability," or how it can "grow enormously without the least change in its molecular structure." This assumed stability of molecular structure, and definite chemical composition of the germ cells, appeared to be necessary to give plausibility to the claim of immortality, and the further assumption of the non-inheritance of acquired characters. The transmission of a definite, stable, self-propagating substance from one generation to another, uninfluenced by the body plasma, has in fact been the shibboleth of those who deny the transmission of acquired characters, but Weismann himself has retreated from this stronghold of his theory as he found it untenable.

In reply to the criticism of Professor Vines that it was "absurd to say that an immortal substance can be converted into a mortal substance," Professor Weismann without hesitation abandons the conception of molecular stability in the germ plasma and presents his theory of heredity in a new form that is more in accordance with physiological laws, and at the same time appears to be fatal to the assumptions made by his followers. He says, "Does not life here as elsewhere depend on metabolism—that is to say, a constant change of material? And what is it then which is immortal? *Clearly, not the substance*, but only a definite form of activity."—"*An immortal, unalterable living substance does not exist, but only immortal forms of activity of organized matter.*" The material continuity of the germ plasma is therefore discarded and replaced with the conception of *modes of motion* manifest in matter that is continually undergoing metabolic changes. As the complex molecular substance of the germ plasma is brought into intimate relations with the metabolism of the body plasma, through its own metabolic activities, we can readily perceive how acquired habits of the organism in modifying the general and special metabolism of the body must also have an influence on the substance of the germ cells, and through their constantly changing substance on the forms of activity, or modes of motion, that are transmitted from one generation to another in accordance with the new theory. It must then be evident that the assumed independence of the germ plasma of all influence from the surrounding body plasma, that is relied on to prove the non-inheritance of acquired characters, derives no support from the present conditions of physiological science.

There are many functional variations in the activities of the different organs of the body that can only be attributed to changes in the environment and food supply, in connection with the habits of the individual, and they are so clearly defined and of such frequent occurrence that it seems to be unnecessary to assume fortuitous variations in the germ cells as the sole factors for natural selection to act upon. In order to evolve two adult forms that are precisely alike in every detail, from two germs with the same identical qualities and tendencies, there must be in each case the same metabolic activity of every part of the system, giving rise to the same series of anastates in the constructive processes of every organ, and the same series of katastates in destructive metabolism, throughout the entire period of growth, which would of course rarely occur from a lack of uniformity in the surrounding conditions of the two individuals.

Individual variations, which are so frequently observed, are then readily accounted for, and there are no physiological reasons for the assumption that the metabolic bias of the organism which gives rise to them does not likewise have an influence on the germ cells.

The non-appearance of an acquired habit or peculiarity of the organism in the next generation cannot be accepted as evidence that it has not been potentially transmitted. The known facts of atavism show that an inherited peculiarity of the organism may be obscured for several generations by other characters, and then reassert itself with all its original intensity. The established family characters, and the acquired habit or peculiarity of the individual represent antagonistic factors, and their relative intensity in connection with conditions of development must determine which is to dominate in the offspring. The transmission of a character, in the first place, should not be manifest in a direct reproduction of the morphological peculiarity, but it must consist in a habit of the organism that leads to the development of the peculiarity in the offspring under favorable conditions for its exercise. The failure of the effects of injuries or mutilations to make their appearance in the offspring cannot be admitted as evidence to prove the non-inheritance of acquired characters, as the physiological activities of the system that are required to produce the morphological peculiarity have not been established and there can be no tendency of the organism to reproduce them.

The repetition of an acquired habit for several generations, under the same conditions, may be required to establish it as a dominant character over inherited family traits that have been fixed by transmission through a long line of ancestors, but the final result would show that it had been uniformly transmitted, although it had been for a time obscured by other prevailing hereditary tendencies of the organism.

In discussing the evidence relating to the inheritance of acquired characters, or the effects of use and disuse, these antagonisms in hereditary tendencies should not be lost sight of, as the immediate results looked for may be obscured for a time by other predominant influences.

The development of the improved breeds of live stock furnishes abundant evidence of the inheritance of acquired characters, but the limits of this paper will only permit a passing notice of its significance. The most successful breeders of domestic animals have acted on the principle that habits of the organs of nutrition, which determine the expenditure of the available energy of foods in a special direction, may be cultivated and intensified by persistent exercise for a number of generations, and it is difficult to explain how the gradual improvement of the desired qualities are obtained without the transmission of the modified habit.

The capacity to fatten at an early age, or, for abundant milk production is promoted by liberal feeding, in connection with a judicious exercise of the desired habit of the system, and the highest excellence is obtained when the system of management in each generation is especially directed to the cultivation of the habit in its integrity. This is particularly noticeable in the habit of milk production for a more or less extended period in the course of the year. The fashion of raising lambs by nurses of other breeds, and drying up the dam at once to keep her in show condition, resulted in seriously diminishing the inherited capacity for milk production in the females of the families so treated. It is well known to farmers that cows on short pastures and under careless management will form the habit of "going dry" early in the season, and that this habit of giving milk for a short period is not only transmitted, but becomes a marked peculiarity of the females of the family that is persisted in under better conditions of food supply.

It appears to be unnecessary to assume fortuitous changes in the germ cells to account for the increase, or the suspension of functions that can be so clearly traced to an acquired ancestral habit. Morphological peculiarities are not the only ones that give character to an organism and determine its significant qualities. As in isomeric compounds in chemistry, we find living organisms that are, so far as we can determine, morphologically identical that differ widely in their habits and general properties. Even in the higher animals the same organ may perform a variety of functions, as the liver for example, and the dominant function for the time being seems to be determined by the requirements of other organs, or of the general system under the special conditions in which it is placed.

There are many species of microbes having the same form and structure that are distinguished by their habits, or the katastates formed in their processes of metabolism, and these katabolic products known as toxines, tox-albumins, ptomaines, etc., differ widely in their specific properties. Peculiarities in the functional activity of certain organs, or of the general system, appear to be transmitted with the same uniformity and certainty as morphological characters that are more readily observed, although not more significant as distinguishing characteristics.

The experiments of Dr. Dallinger with three species of monads, under prescribed conditions of temperature, are of particular interest in showing that the modified or acquired habits of organisms are beyond question transmitted to their offspring. From the rapid repetition of the process of reproduction in these organisms by fission and sexual fusion, they have marked advantages in experiments for determining the inheritance of new characters.

Throughout the experiments an abundant supply of suitable food was provided, and beginning with a temperature of 60°, which appeared to be most favorable for them, a gradual increase of temperature was made from time to time as they were able to endure it, until a final temperature of 158° was reached, in the course of seven years, at which there appeared to be a perfect adjustment of their vital activities to the abnormal environment.

There were critical periods, as the temperature was increased, at which a considerable time was required for the organisms to become fully acclimated, and when this was secured a more rapid increase of temperature was for a time admissible, until another point was reached at which a further rise in temperature could not for some time be made.

No advance was possible for eight months after the temperature of 78° was reached; at 93° a halt of nine months was required; and at 137° a further increase of temperature was not permitted until after twelve months had elapsed. The manner in which the organisms were affected at the critical periods will be sufficiently illustrated by Dr. Dallinger's remarks on their behavior at 137°. He says: "When the 136th degree had been passed there were symptoms of oppression and distress, and on touching 137° this was very manifest," and it was found necessary "to play the thermal point backwards and forwards for three weeks before there was an approach to normal activity and fecundity." At the close of the twelve months, during which the temperature was maintained at 137°, there was an increase in the vacuolation of the protoplasm, which disappeared on raising the temperature 4° in the following month. From this time more rapid progress was made until the final temperature of 158° was reached, when the experiment was terminated by an accident to the apparatus for regulating the temperature.

At times a slight increase of temperature was not tolerated until the changed habits of their protoplasm provided for the complete adjustment of their vital activities to the new environment, but when this adaptation was fully attained there was apparently developed an increased flexibility of their organization that enabled them for a time to bear a comparatively rapid rise of temperature without any perceptible discomfort, but a limit to this toleration was again soon reached. The organisms that had been trained to live at a temperature of 158° with apparent satisfaction, and exhibiting a normal exercise of their nutritive and reproductive functions, were, however, killed when subjected to a temperature of 60°, which was the most favorable for their ancestors.

The acquired habit of adjusting their physiological activities to an abnormally high temperature was undoubtedly transmitted through many thousand generations, and it is evident that the germ plasma was affected by the changes of the environment, either directly, or with greater probability through the modified metabolism of the body plasma.

These experiments clearly indicate the importance of time, in some species at least, as a factor in the complete adjustment of even functional activities to changes in the environment. Seven years of persistent effort was required to bring about a change in the habits or metabolic processes of these organisms, that enabled them to endure or actually enjoy the final temperature of 158°, and a much longer time was evidently needed to produce any marked morphological changes.

The transformations of energy in the metabolic processes of nutrition appear to be probable causes of variation, and possible factors in evolution, that require investigation. The effects of use and disuse are not obvious in many organs of an obscure nature, and undetermined function, some of which may have intimate relations with the dynamic factors of nutrition, and thus serve a useful purpose which we are now unable to perceive.

What are the relations of the so-called ductless glands, like the thyroid and supra-renal capsules, to the utilization and conservation of energy? Are not the polar bodies of the ovum, and the thymus of the embryo, temporary organs to transfer and conserve energy under special conditions that disappear at later stages of development?

What molecular or other changes take place in the organism to bring about an intense activity of special functions, involving a more complete utilization of energy, as in increased milk production, or in improved fattening qualities?

Questions like these must be answered to furnish a satisfactory explanation of biological activities, and theories of nutrition and heredity in which energy is not recognized as one of the prime factors in every vital process, should be received with caution, and the fallacious arguments based upon them estimated at their real value.

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ON THE SUPPOSED CORRELATIONS OF QUALITY IN FRUITS—A STUDY IN EVOLUTION. By Prof. L. H. BAILEY, Cornell University, Ithaca, N. Y.

[ABSTRACT.]

IT is commonly supposed that as quality in cultivated fruits increases, various other characters, as size, color and vigor of plant, decrease. The question is a philosophical one, for its answer must determine whether cultivated plants are subject to the same laws of variation as their wild congeners, whether all characters vary independently, or whether cultivation introduces some new law of progression in parallelisms. The subject is approached by a study of the scales of points used in the best fruit-lists, by which it becomes apparent that many desirable qualities often appear in the same variety of fruit, and that many of our best market fruits are also best for the dessert. The best records show that diminished size, low color, comparative seedlessness, tenderness of tree, and lessened vigor are not correlated with high flavor. It is also shown that there is no loss of sweetness or aroma in domesticated fruits which is due to cultivation and amelioration. "It is evident from our whole discussion that quality and other characters of cultivated fruits appear independently of each other, that there is no correlation between these characters. There is a general increase in all characters as amelioration progresses, at least in all characters which are particularly sought by horticulturists; and this fact must ever remain the chief inspiration to man in the amelioration of plants."

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THE SIGNIFICANCE OF CLEISTOGAMY. By THOMAS MEEHAN, Vice President of the Academy of Natural Sciences of Philadelphia, Pa.

[ABSTRACT.]

THE author defines cleistogamy in a limited sense, as relating to those flowers, which, fertilizing in the bud, have parts of their floral organs suppressed or modified,—though in a general sense those which fertilize in the bud, without such modification, might be included.

He contrasts the limited number of natural orders in which cleistogamy was known when Mr. Darwin wrote "Forms of Flowers," with the larger list now existing, and suggests that the additional facts may modify Mr. Darwin's conclusion that the significance of cleistogamy was a mere labor-saving draft on the nutritive forces. He refers to his recent discovery that *Dalibarda repens* is cleistogamic, and to his former recorded discovery that all the fertile flowers of most Polygoni are absolutely closed and self-fertile, while the open, apparently perfect, and nectar-secreting flowers are sterile,—to the enormously productive power of cleistogene nemophilas and other plants—to the great waste of nutrition in producing petaliferous but sterile flowers in so many plants which produce cleistogene ones, and concludes that there is much greater waste of effort under these conditions than in plants which self-fertilize without producing cleistogamic flowers.

His view is that cleistogamy is simply one of the phases in the struggle for ascendancy between the vegetative and the reproductive forces, and of no especial significance so far as any benefit to the individual or the race is concerned.

[This paper has been published in full in the London Gardener's Chronicle for Oct. 1, 1892, p. 398.]

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THE FERTILIZATION OF PEAR FLOWERS. By M. B. WAITE, Dept. of Agric., Washington, D. C.

[ABSTRACT].

THE paper gives a brief general account of a large series of experiments on the fertilization of pear flowers. Notes the abundant insect visitors and the effect of climatic conditions on them. The conclusions reached are: (1) That some cultivated varieties of pear are capable of self fertilization but that the majority are not. (2) That cross-fertilization is effected by insects and (3) that cross fertilization, at least the kind required for the selling of fruits, consists in crossing one horticultural variety with another and not in crossing one tree of a certain variety with another of the same name.

[This paper will be printed in Dept. of Agriculture Bulletin.]

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GERMINATION AT INTERVALS OF SEED TREATED WITH FUNGICIDES. By W. A. KELLERMAN, Ph.D., Ohio State University, Columbus, Ohio.

[ABSTRACT.]

EXPERIMENTS in connection with a study of fungicides for smut of oats have shown that seed treated with hot water and with solutions of potassic sulphide germinates more quickly than untreated seed. Experiments of Dr. J. C. Arthur with seed treated with hot water gave a similar result. He showed, moreover, that the treated seed would continue to germinate more quickly after a considerable period of time had elapsed. Experiments

touching this matter were instituted. Oats and corn were used. The seed was treated with water, 132° F. fifteen minutes; and with potassium sulphide ½% solution eight hours, and the same twenty-four hours. The following table of percentages of germination gives the summary of results:—

| When tested | Untreated seed. | | | | Treated seed. | | | |
|---|---|---|---|---|---|---|---|---|
| | 1st day | 2d day | 3d day | 8th day | 1st day | 2d day | 3d day | 8th day |
| At time of treatm't | 0 | 22 | 62 | 99 | 10 | 53 | 75 | 94 |
| 5½ mos. after treatm't | 0 | 26 | 58 | 98 | 0 | 37 | 53 | 98 |
| 13½ " " " | 1 | 69 | 90 | 98 | 0 | 30 | 60 | 79 |

Rather low temperature at the time of the first test (July 1, 1891) in the above table unfortunately reduced the germination the second day.

It is evident (1) that the germination of the treated seed is more rapid than of the untreated seed immediately after the treatment, and (2) That this ratio continuously declines with time and the germination is ultimately less rapid and inferior.

Besides, the seed which was treated twenty-four hours with a one-half per cent solution of potassic sulphide twenty-four hours, though germinating well at first, lost its germinating power to a remarkable degree subsequently as the following table shows:—

PERCENTAGE GERMINATION OF CORN.

| When tested | Mode of treatment of the seed. | Germination. | | | |
|---|---|---|---|---|---|
| | | 1st day | 2d day | 3d day | 8th day |
| At time of treatment | UNTREATED. | 0 | 12 | 35 | 100 |
| " | Water, 132° F. 15 min. | 0 | 23 | 53 | 100 |
| " | $K_2S$, ½% solution 8 hrs. | 0 | 36 | 70 | 100 |
| " | $K_2S$, " " 24 " | 42 | 85 | 97 | 100 |
| 5½ months after treatment | UNTREATED. | 0 | 1 | 29 | 99 |
| " | Water, 132° F. 15 min. | 0 | 5 | 37 | 99 |
| " | $K_2S$, ½% solution 8 hrs. | 0 | 0 | 14 | 97 |
| " | $K_2S$, " " 24 " | 0 | 0 | 1 | 75 |
| 13½ months after treatment | UNTREATED. | 0 | 70 | 97 | 97 |
| " | Water, 132° F. 15 min. | 0 | 38 | 96 | 99 |
| " | $K_2S$, ½% solution 8 hrs. | 0 | 33 | 92 | 97 |
| " | $K_2S$, " " 24 " | 0 | 2 | 15 | 66 |

THE FERTILIZATION OF THE FIG AND CAPRIFICATION. By C. V. RILEY, Ph.D., U. S. Dept. Agric., Washington, D. C.

[ABSTRACT.]

IN the production of the best Smyrna figs, certain minute insects are concerned in a manner which is very puzzling to the lay mind. The subject of caprification is, in fact, most complicated, and has occupied the attention of some of the best investigators; and since fig culture is rapidly becoming an important industry in parts of the United States, especially in California, our people are beginning to realize that caprification is necessary to the successful cultivation of the Smyrna figs. The question has been intelligently discussed by Gustav Eisen and other enterprising fruit growers of California, but one of the most conspicuous writers on the subject from San Francisco, instead of adding to our knowledge, has simply obscured the facts and increased the errors.

The term "caprifig" denotes one of the two forms of the cultivated fig tree (*Ficus carica*) and is commonly, though erroneously, called the "Wild Fig Tree." The other form is the fig tree proper, *i. e.*, that form which produces the edible fruit. The caprifig also produces fruit, but it is small and insipid. "Caprification" is a botanico-entomological operation consisting in the transfer of certain minute insects which develop in the seeds of the caprifig to the fig tree proper, in order to secure, through these insects, the fertilization of the female flowers, and thereby the production of the edible fruit. The usual mode of caprification practised from time immemorial in Asia Minor, Greece, Turkey, Southern Italy and Southern Spain is as follows:—On a certain day in the spring of the year the young figs of the caprifig are gathered, two or more of them fastened to the end of a tough reed, and these loaded reeds are then laid or dexterously thrown on the twigs of the true fig tree.

The author here sketched the history of caprification since the days of Aristotle, and gave details of the peculiarities of the fig flowers and of the fig insects, especially of the true caprifig insect, *Blastophaga psenes*. He referred to some twelve different fig insects, most of them new, connected with the wild figs of America, from Florida, Mexico and St. Vincent, and closed with the following practical considerations:—

The Adriatic varieties of figs have been transported by means of layers and cuttings, and are now cultivated in almost every part of the globe possessing a climate suitable to the growth of the fig tree. Thus we see that in the more southern parts of our own country, and more especially in California, where soil and climate appear to be admirably adapted to fig culture, large quantities of figs are produced annually, which, in quality and size, compare favorably with the best Adriatic figs produced in Italy or France. But even the most enthusiastic of these fig growers concede that their figs are inferior in every respect to the Smyrna figs, and all agree that the superiority of the latter consists not so much in their greater size, greater sweetness and pulpiness, as in the delicate flavor of their fertile seeds. Strong efforts have been made in California to introduce the genuine Smyrna fig. Seedlings, cuttings and layers from the most famous fig growers in the Mæander Valley, near Smyrna, have been produced regardless of cost, and extensively planted in California. The trees have grown admirably, but lo! the fruit drops when still quite young, or, in some few instances where it adheres to the branches, remains small and insipid. This failure has been attributed to all sorts of causes: influence of climate, soil, irrigation, dishonesty on the part of dealers in roots and cuttings, etc.; but the true explanation, as given by Mr. Gustav Eisen, who has intelligently studied the subject, was till lately disregarded and ridiculed, the fact having been generally overlooked that the Smyrna fig has always been, and is still cultivated by means of caprification, and that the tree which, in its home, produces fruit with fertile seeds solely by the agency of the Blastophaga, cannot produce the same kind of fruit when transplanted into a country where there are no Blastophagas.

There is but one way to cultivate successfully the genuine Smyrna fig in California, and that is to plant both the female fig trees and the caprifig, and to introduce and colonize the Blastophagas. The planting and raising of the caprifig present no difficulty whatever; it is only necessary to sow the seeds of the genuine Smyrna fig, and both caprifig and true fig trees will result. Indeed this has already been done. But the genuine Blastophagas must also be introduced, for it is highly improbable that the Blastophagas, peculiar to our own wild fig trees in southern Florida and Mexico, are fitted to do the work. The Blastophagas, peculiar to *Ficus carica*, must, therefore, be introduced from their native home in Asia Minor or some other part of the Mediterranean. Fruits of the caprifig or twigs of the tree, with adhering fruit, may doubtless be brought over at the proper season in good condition, *i. e.*, with the Blastophagas within the fruits living and healthy; but success in the experiment depends not only on the good condition of the Blastophagas, but also on the condition of the caprifig trees growing in California at the time of the arrival of the insects. The gall-flowers of the trees must, at that time, have attained just the precise state of development when they are ready for the oviposition of the insects. If they are not advanced enough, or are advanced too far, the acclimatization of the Blastophagas is sure to be a failure. I have for some time recognized the importance of the introduction of these Blastophagas, and have had correspondence with parties in California in reference to the matter. But my plans to send a special agent abroad for this and other purposes have been hitherto frustrated by conditions over which I have had no control. The efforts made last summer, however, by Mr. J. Shinn, of Niles, Alameda Co., and Mr. Gustav Eisen, of San Francisco, have sufficiently proved the practicability of the scheme. A box of caprifigs and Blastophagas arrived in San Francisco last August, many of the insects being alive and apparently just hatched. The figs were collected at Lochia near Smyrna in the last days of June. The box reached Smyrna on the 2d of July, arrived in New York on the 18th, and on the 23d reached Mr. Shinn at Niles, requiring only twenty-five days for the journey; this time being quick enough to insure full success in any similar importations.

So far as I have been able to learn from correspondence, we have no evidence that this effort of Mr. Shinn's was successful. But such enterprises, requiring considerable expenditures, should not be left to private effort, but belong particularly to our National Department of Agriculture; and it is not particularly encouraging to reflect that projects very generally condemned by men of science will be apt to find favor at Washington if they but add to political and appointive power; whereas thoroughly scientific and practical work, which appeals less to political susceptibilities, too often finds little sympathy.

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NOTES ON SELF-POLLINATION OF THE GRAPE. By S. A. BEACH, Geneva, N. Y.

[ABSTRACT.]

THE paper explains that the proper time for examining grape buds to determine whether self-pollination occurs before the flowers open is just at the time when dehiscence of the corolla begins. The process of dehiscence and self-pollination is then explained. The total number of individuals in which self-pollination was observed is seventy-seven, distributed among eight species and their hybrids and crosses.

Clusters of grapes were inclosed in bags before blossoming to prevent the access of foreign pollen. Three cultural varieties having pure *Labrusca* blood were found to be fully self-fertile and a fourth was nearly so. Of seventeen hybrids and one cross having *Labrusca* and *Vinifera* blood three were fully self-fertile; these had long filaments. One partly self-fertile also has long filaments. Eleven had pollen self-irritant only. So far as known these had short filaments. One had pollen self-impotent; it has short filaments. Every one of these eighteen plants having short filaments is practically pistillate, every one with long filaments is self-fertile. A specimen of *Aestivalis* has long filaments and is self-fertile; the same is also true of the Delaware (hybrid of *Vinifera* and *Riparia?*). *Vitis Doaniana* as represented by a vineyard specimen has pollen self-irritant only.

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ADAPTATIONS OF PLANTS TO EXTERNAL ENVIRONMENT. By WILLIAM P. WILSON, 640 N. 32d St., Philadelphia, Pa.

[ABSTRACT.]

A COMPARISON of various lowland vegetation with that of desert and mountain areas.

Illustrated by photos and drawings from the living plants.

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THE COMPARATIVE INFLUENCE OF ODOR AND COLOR OF FLOWERS IN ATTRACTING INSECTS. By GEO. B. SUDWORTH, Forestry Division, Dep't of Agric., Washington, D. C.

[ABSTRACT.]

THE author of this paper called attention to a supposed evolution, or development from a low to a high grade in the colors of flowers, ranging from

"the simplest, yellow; second, white; third, pink to red; fourth, the most perfect color, blue." He spoke then of his own and other experiments which seemed to prove that nectar-gathering insects of higher orders (honey bees, etc.,) show a preference for the higher-grade colored flowers. He believes, however, that the comparative attractability of color is less powerful in its influence on insects than that of odor, his experiments showing, first, that honey bees work persistently upon syrup scented with an artificial sweet odor (anise), but refuse to take the same sweet when unscented; and second, his experiments showed that color does not attract insects at all when tested equally with an odor, the supply of sweet to be obtained in connection with the color and odor test being equal in both cases.

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A COMPARATIVE STUDY OF THE ROOTS OF RANUNCULACEÆ. By Dr. F. B. MAXWELL, Rockford, Ill. Presented by W. R. DUDLEY.

[ABSTRACT.]

THIS paper contains the results of the microscopic examination of the roots of about thirty species of Ranunculaceæ, native to the northern United States, including a comparative study of the apical meristem and of the changes taking place through secondary growth.

The authorities on meristem structure, so far as they have treated of the roots of this natural order, have assigned them to a single type, while the writer finds there are two principal types represented, each including a considerable number of species, and has also made a subsidiary type for the roots of two species.

It is usually assumed that secondary changes take place to a greater or less extent, in the mature roots of Dicotyledons. The present study demonstrates, however, that in many Ranunculaceæ, the primary structure persists in the older root. On the basis of the changes taking place through secondary growth, the author has made three classes for the roots studied.

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THE ROOT-SYSTEM OF MIKANIA SCANDENS L. By W. W. ROWLEE, INSTRUCTOR IN BOTANY, Cornell Univ., Ithaca, N. Y.

[ABSTRACT.]

MANY aquatic plants develop roots that exist in the water and never reach the soil. *Mikania scandens* develops a great number of these roots. A few appear upon the plant during its growth in summer, but the greatest development of the root-system is during and after flowering in the autumn. In the earlier part of the season they show comparatively little tendency to branch; in autumn the branching is immense. At this time most of the rootlets spring from the larger roots, but many come from the lower part of the stem especially the nodes. All these roots are

negatively geotropic. They come to the surface of the water and either float there or rise above it. If the water rises above them, they will grow longer.

If the plant be transplanted to a dry place, it will still develop this root-system. The rootlets, however, do not attain so great a length, but stop just above the surface of the ground forming a multitude of little "knees" about an inch or less high.

The structure of these rootlets is as follows:—In the center is the plerome in the circumference of which is the fibro-vascular system. This is of the regular radial type. The xylem portion is only feebly developed. The cells of the phloem portion consists of only six or eight cells, slightly smaller than the surrounding parenchymatous cells of the plerome. The phloem takes a decidedly deeper stain with haematoxylin than does the surrounding tissue. A distinct endodermis surrounds the plerome, and its cells are in contact with the outermost cells of the phloem. Four cells (in the section) are peculiarly modified. Two belong to the endodermis, two to the row of cells just outside of it. These cells always lie in contact with the cells of the phloem. They are so arranged as to enclose a rectangular intercellular space between them of considerable size and definite shape. They have large nuclei and these are always upon the side of the cell next to the intercellular space. The cortex of the root is made up of loose parenchyma tissue but in no other part of it are regularly organized intercellular spaces. The root is covered with a thin epidermis. The intercellular spaces above mentioned extend to very near the growing point of the root.

In longisection the strongly nucleated cells form a conspicuous lining to the intercellular spaces. It seems highly probable that these spaces, regularly organized in connection with the phloem portion of the root, have some special function. This, taken in connection with the peculiar development of these roots and their place of growth, is strong evidence in favor of their performing the function of aëration.

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GEOGRAPHIC RELATIONSHIP OF THE FLORA OF THE HIGH SIERRA NEVADA, CALIFORNIA. By FREDERICK VERNON COVILLE, Department of Agriculture, Washington, D. C.

[ABSTRACT.]

A LIST of representative species of the high Sierra Nevada is given. A comparison of these plants with those found in the Rocky mountains and the Cascade mountains shows (1) a large endemic flora of the Sierra Nevada; (2) a group of species common to all three ranges; (3) a group common only to the Sierra Nevada and the Cascade mountains; (4) a group common only to the Sierra Nevada and the Rocky mountains.

[This paper will be printed in Contributions from the U. S. National Herbarium.]

CHARACTERISTICS AND ADAPTATIONS OF DESERT VEGETATION. By FREDERICK VERNON COVILLE, Department of Agriculture, Washington, D. C.

[ABSTRACT.]

SOURCE and distribution of moisture. Conservation of moisture. Temperature. Seasons. List of species of the Mohave Desert, arranged by groups. General adaptations. Particular modifications.

[This paper will be printed in Contributions from the U. S. National Herbarium.]

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NOTES ON A MONOGRAPH OF THE NORTH AMERICAN SPECIES OF LESPEDEZA. By Prof. N. L. BRITTON, Columbia College, New York, N. Y.

[ABSTRACT.]

A DISCUSSION of the American species of this genus, illustrated by specimens.

[This paper will be printed in Bulletin of the Torrey Botanical Club.]

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NOTES ON RANUNCULUS REPENS AND ITS EASTERN NORTH AMERICAN ALLIES. By Prof. N. L. BRITTON, Columbia College, New York, N. Y.

[ABSTRACT.]

A DISCUSSION of the relationships of the European *Ranunculus repens* to several North American species. Illustrated by specimens.

[This paper will be printed in Transactions of the New York Academy of Sciences.]

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PRELIMINARY COMPARISON OF THE HEPATIC FLORA OF BOREAL AND SUB-BOREAL REGIONS. By Prof. LUCIEN MARCUS UNDERWOOD, Greencastle, Indiana.

[ABSTRACT.]

RECENT explorations in boreal America and Asia enable us to make comparisons with flora of Europe which is better known. Of about 575 Hepaticæ from north temperate and arctic zones, 375 are European, 300 American and about 150 Asiatic. In the boreal and sub-boreal portions there are 173 north European species, 163 species in northern America and 98 species in northern Asia. Fourfold difficulties in studying northern flora of America are :— (1) Necessity of close familiarity with European species, varieties and forms; (2) Undue refinement of species in certain genera; (3) Periodic upheaval of nomenclature; (4) Inacessibility of types and uncertainty of European authorities and exsiccatæ.

Deductions from study :—

1. Of 214 boreal species, 80% are European, 76% are American, and 46% are Asiatic, the last doubtless due to less extensive exploration.

2. 78% of American species are found in Europe, 42% in Asia, 20% are endemic.

3. 86% of Asiatic species are found in Europe, 9% are endemic.

4. 15% of European species are endemic.

5. 67 species are circumpolar.

6. Certain northern hemisphere genera predominate in greater proportion than elsewhere. (Notably *Cephalozia*, *Marsupella*, *Scapania*, *Jungermania*.)

7. 37 genera are represented among 98 Asiatic species; *Calycularia* alone endemic.

8. Two European genera, *Scalia* and *Pleurozia* not found in either America or Asia.

9. The genera *Aitonia*, *Anthoceros*, *Fossombronia*, *Herberta*, *Hygrobiella*, *Jubula*, *Liochlæna*, *Marsupella*, *Pallavicinia* and *Pleuroclada* of boreal America and Europe (together with *Sphærocarpus*, *Dumortiera*, *Lunularia*, *Targionia* and *Notothylas* from lower latitudes) have not yet appeared in Asia.

10. Tabular comparisons of the larger genera summarizing distribution.

11–17. Lists of species common and endemic giving the data for above deductions.

[This paper will be printed in Botanical Gazette.]

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A STUDY OF THE RELATIVE LENGTHS OF THE SHEATHS AND INTERNODES OF GRASSES FOR THE PURPOSE OF DETERMINING TO WHAT EXTENT THIS IS A RELIABLE SPECIFIC CHARACTER. By Dr. WM. J. BEAL, Agricultural College, Mich.

[ABSTRACT.]

SOME agrostologists use the character above mentioned; some do not. Ten to thirty plants of forty-seven species were examined and the internodes and sheaths measured and tabulated. In thirty-five species the character is a good one. In very variable grasses it is of less importance. In no case would it be safe to rely on one or two stems alone. The sheaths and internodes of very tall specimens or very short ones are usually much less reliable for specific character in this point, than those of a common height. The second and third sheaths and internodes from the top are more reliable for this purpose than are the upper ones or those lower down. The sheaths seldom follow any exact proportion when compared with corresponding internodes, but often do so within moderate limits.

[This paper was illustrated by diagrams.]

PLEOSPORA OF TROPÆOLUM MAJUS. By Prof. BYRON D. HALSTED, Rutgers College, New Brunswick, N. J.

[ABSTRACT.]

A FUNGUS of the Alternaria type was found upon foliage of garden nasturtium (*Tropæolum majus*) associated with perithecia of a Pleospora. Cultures were made of the Alternaria spores upon slant agar tubes and a pure growth of the black mould obtained followed by the ascigerous form *in*, and not upon the surface of the agar. The perithecia were of many and strange shapes not at all resembling those of the leaves except in the cellular structure of the wall and the size and shape of the spores. This was an unusual instance of the direct modification of the surrounding media upon the size and form of the perithecia. The history of the formation of the perithecia was easily made out and while there were hints of the presence of the process of fertilization it was not demonstrated.

The species is apparently new and while it approaches *Pleospora Americana* E. and E. upon the pea it differs in several characteristics. Following the ordinary rule of recognizing the host in the specific term the name of the species in hand may well be *Pleospora tropæoli* n. s.

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SECONDARY SPORES OF ANTHRACNOSES. By Prof. BYRON D. HALSTED, New Brunswick, N. J.

[ABSTRACT.]

A STUDY of the germinating spores of species of Anthracnoses teaches that the formation of the "special cells" or "secondary spores" is probably confined to two genera namely: Glœosporium and Colletotrichum. They seem to be constantly present in these two genera. Those conditions which are not especially favorable for the production of ordinary spores are well adapted to the formation of the secondary spores. There is some uniformity in the color and shape of the special cells but more in the position they occupy upon the filament.

The nature of these cells is not easily determined. They seem to be bodies for enduring periods unfavorable for the growth of the fungus. These cells sometimes increase in number and form a sclerotium as is well known among some other fungi. Twenty-four species of spores were studied.

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A BACTERIUM OF PHASEOLUS. By Prof. BYRON D. HALSTED, Rutgers College, New Brunswick, N. J.

[ABSTRACT.]

COMPLAINTS of a serious disease of beans with samples were received from a large seed-growing firm. The diseased beans were small and were marked at one or more places with brown irregular somewhat sunken spots. When sown they failed to produce healthy plants and when placed on perforated porcelain plates over water they began soon to decay.

An examination previously made revealed no filamentous fungus, and therefore there were strong suspicions of a bacterial trouble. The fact of easy inoculation was demonstrated and the microscopic examination of the diseased tissue showed the constant presence of a germ.

The bacterium is characterized by its peculiar habit of growth. In itself the cells are oval 1.5$^{\mu}$ by 2.5$^{\mu}$ and when seen in rapid growth are arranged in bent and twisted chains. The organism prefers the exposed surface of nutrient media as plugs of radish and sweet potato roots to the interior, and produce a thick patch becoming almost milk white with age.

The reproduction of the spots upon beans involves perhaps insurmountable difficulties as the germ probably effects its entrance while the seed is quite young and before the coat is tough. The germ has been grown upon young beans *in situ* in split pods in tube cultures.

(Samples of diseased beans and cultures were shown.)

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NON-PARASITIC BACTERIA IN VEGETABLE TISSUE. By H. L. RUSSELL, Univ. of Chicago.

[ABSTRACT.]

THE evidence is conclusive that the tissues of the animal body are in a healthy state, free from bacteria, but the proof is not as strong with respect to plant life and micro-organisms. The following experiments which were carried out in another connection may help to throw some light upon this question and may serve to explain the contradictory results that have been brought forth from time to time.

Healthy plants were infected with various species of bacteria, saprophytic as well as those that are pathogenic for animals, in order to see, first, the effect if any, of the micro-organisms upon the plant, and second, the reciprocal effect of the host upon the micro-organism. Macroscopically, no change was evident when the various species were inoculated into healthy plants. Microscopically, the condition was much the same, except in the case of *B. Pyocyaneus* in geranium when the plant's vitality was purposely weakened and then the organism was able to penetrate the tissues.

The effect of the plant and its juices on the micro-organisms was however quite different. All the pathogenic species except *B. Pyocyaneus* died under the unfavorable conditions which surrounded them, but not a few of the saprophytic species such as *B. butyricus*, *B. prodigiosus*, *B. luteus*, *B. coli commune*, and *B. acidi lactici* were to be found in a living condition after a period of incubation in the plant ranging from fifty to seventy days. A peculiarity of their presence was that they were not only present at point of introduction but were to be found at varying distances *above* the point of inoculation. This indicates that saprophytic species *can* at least *live* in vegetable tissue for a not inconsiderable length of time so that it is easy to see how bacteria could obtain an entrance to the plant by means of a wound and then become enclosed by the healing over of the wounded tissues. Such tissue may to all appearances remain perfectly healthy and still it is possible that it may contain bacteria.

In this connection I have also made numerous attempts to isolate bacteria from different forms of vegetable tissue where I first made sure that there were no previously existing wounds, but in no case have I been able to find micro-organisms present.

The evident conclusion from my experiments is that healthy plant tissue like animal tissues is normally free from bacteria; but that, unlike the animal tissue, many micro-organisms are able not only to exist within the tissues of plants but possibly possess some powers of multiplication.

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## Bacteriological investigation of marine waters and the seafloor.

By Dr. H. L. Russell, University of Chicago, Chicago, Ill.

[Abstract.]

The observations stated below give in bare outline the results obtained by the analysis of marine waters and underlying mud from a bacteriological standpoint. This field of bacteriology has heretofore been left quite untouched but in the present discussion mention can only be made of the more salient points.

After detailing the methods used in securing the water and mud and the methods of analysis that were adopted, the author gave some of the more prominent conclusions that he had drawn from the study of the marine water and mud, which had been carried on at Naples and also at Wood's Holl, Mass., during the past two years.

I. The marine waters are inhabited by a specialized bacterial flora that is present in the waters irrespective of land proximity. Outside of the line of coastal contamination, no marked variation could be traced in the contents of the superficial waters other than that attributable to local variation. In regard to the vertical distribution of germs the same result was found. The water from 2500 feet deep contained quite as many as did that from the surface.

II. The marine mud is likewise rich in micro-organisms. Indeed, as regards numbers per unit of volume, the mud is infinitely richer in germ life than the superincumbent water masses. These numbers vary greatly. Near Naples at the depth of 150 feet and two miles from land, the mud of the sea bottom yields 200,000 to 300,000 germs per cc. This number fell rapidly as the depth increased until at 3,500 feet, there were only about 25,000 per unit of measure.

The work at Wood's Holl this year shows that the mud at this point is much less rich than the Mediterranean slime. Here it ranged from 10,000 to 30,000 germs at a depth of thirty to sixty feet and outside of land contamination. The excess of the mud over the water contents is brought about largely by the growth of *indigenous* mud forms as revealed by qualitative analysis. These species are distinctively mud-living in their habitat and are only found in the slime at the bottom. They did not reach their present position by deposition from above, but have gradually worked their way along the sea bottom. By means of differential cultures, the actual condition of the germs in water and mud was determined and it was found that both mud and water were richly endowed with bacterial life in an actively vegetating condition.

In regard to the species distribution some points were also brought out. The bathymetrical range of the predominating species was in some cases determined and it was found that the same species was able to live at widely different depths, the limits of growth exceeding in some cases 3,500 feet.

When the difference in environment at the surface and at this depth is considered, it will be seen that certain forms have a remarkable power of adaptation. The comparative work at Naples and Wood's Holl also gave an opportunity to determine the universality of species distribution geographically.

At Wood's Holl, besides working over quite thoroughly the region of Buzzard's Bay and Vineyard Sound, samples were also taken on the Grampus, the U. S. F. C. schooner, at a distance of 100 miles from land and the same species in general were found to be distributed over this entire area. The species found at Naples were quite different with but one exception from those isolated on our Atlantic coast. One of the most marked of the Naples forms was also found to be an occasional inhabitant of the ocean slime on this side showing that the distribution in this particular instance was quite widespread.

[This paper will be printed in the Botanical Gazette.]

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## On the value of wood ashes in the treatment of peach yellows.

By Erwin F. Smith, U. S. Dep't or Agriculture, Washington, D. C.

[ABSTRACT.]

These experiments were undertaken for the United States Department of Agriculture. They were begun in the spring of 1389.

The orchard is about seven miles south of Dover, Del., in what was formerly considered one of the most productive and valuable peach regions of the State. The locality contains many extensive orchards seriously injured by yellows and rapidly becoming worthless. This field was set in the spring of 1882 and contained about 2,800 trees, 20 x 20 feet apart, *i. e.* 108 per acre. The trees have been thoroughly cultivated and otherwise well cared for. They grew vigorously and all of them were healthy for four years. In 1886 there were 3 cases of yellows; in 1887, 257; in 1888, 314. The remainder of the orchard was healthy and thrifty in the spring of 1889, and the trees were of quite uniform growth.

The field is a level tract only a few miles distant and not many feet above Delaware bay. The soil is a light loam resting on several feet of porous yellow clay beneath which are yellowish and reddish stratified sands.

Five plats were selected for treatment. Each consisted of a double row,

separated from the next treated plat by a double row of untreated trees. The treated plats contained 135 trees; the untreated, 136. In the spring of 1889 there were four cases on the untreated, leaving 132 healthy trees. The treated plats contained ten cases, leaving 125 healthy trees. Eight of these ten cases were on one plat, and if they exerted any influence on the results it must have acted equally on treated and untreated.

The treatment consisted of strong, unleached, hard-wood ashes applied twice as follows:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| AA | 136, lbs. | per tree, | May 8, 1889; | 136, lbs. | per tree, | April 22, 1890. |
| BB | 88, " | " | " | 88, " | " | " |
| CC | 69, " | " | " | 69, " | " | " |
| DD | 48, " | " | " | 48, " | " | " |
| EE | 45, " | " | " | 45, " | " | " |

The ashes were sowed on plowed ground and harrowed in. The soil was also plowed and harrowed in 1891 and 1892. No effect on the foliage was noticeable until the second season.

The results are as follows:

(1) None of the ten diseased trees were cured. Other cases appeared

(2) The cases did not become numerous until more than a year after the first treatment, *i. e.*, until the ashes had had time to become blended with the soil.

(3) One of the controls remained freer from disease than any of the treated plats, and very free until 1892 when nearly all of the trees became affected.

(4) Almost all of the treated trees succumbed to the disease in 3½ years.

(5) The såme is true of the untreated, but a comparison by years up to the fall of 1891 shows that the disease progressed more slowly among the untreated.

(6) Light and heavy treatments were equally ineffectual in staying the progress of the disease.

The cases by years and the per cents. are given in the following table.

| | TREATED—5 PLATS—125 HEALTHY TREES. | | | | UNTREATED—5 PLATS—132 HEALTHY TREES | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | 1889 | 1890 | 1891 | 1892 | Total | Total | 1892 | 1891 | 1890 | 1889 |
| Cases | 2 | 29 | 42 | 42 | 115 | 116 | 55 | 33 | 26 | 2 |
| % | 1.6 | 23.2 | 33.6 | 33.6 | 92.0 | 88.0 | 41.7 | 25.0 | 19.7 | 1.5 |

The conclusion is that peach yellows cannot be cured or prevented by the use of wood ashes.

[This paper will be printed in substance in Dep't of Agric. Bulletin.]

ON THE VALUE OF SUPERPHOSPHATES AND MURIATE OF POTASH IN THE TREATMENT OF PEACH YELLOWS. By ERWIN F. SMITH, U. S. Dept. of Agriculture, Washington, D. C.

[ABSTRACT.]

THE experiments here described form part of a large number undertaken by the U. S. Department of Agriculture in the spring of 1889, and continued three years.

The orchard is in the north part of Kent County, Md., in a great peach region now seriously affected by yellows. It includes about 2,900 trees set in 1881, and cultivated in the usual way. The trees grew thriftily and all of them were healthy for five years. In 1886, there were four cases of yellows; in 1887, 318; in 1888, 300. The remainder of the orchard was still in good condition in the spring of 1889. The field is a level upland only a short distance from Chesapeake bay. The soil is rather stiff loam on a yellow clay subsoil resting in turn on a deep red clay.

For treatment ten plats were selected in various parts of the orchard so as to fairly represent the whole. Each was then subdivided so as to make twenty in all. These plats contained 644 healthy trees, and fewer cases of yellows than any other areas of like size. For comparison ten equally representative plats were selected. These contained 810 healthy trees, but a slightly greater per cent of cases of yellows. The remainder of the orchard contained many healthy trees, but was least free from disease.

The twenty plats (ten subdivided) received four treatments with a mixture consisting of kieserite 4%; muriate of potash 24%; and dissolved bone black 72%. The treatments were given in the spring of 1889, autumn of 1889, spring of 1890, and spring of 1891. During the course of the two years each tree received about 12 lbs. of this mixture. The north half of each plat also received two extra treatments with muriate of potash. This was put on in the springs of 1889 and 1891, at the rate each time of two lbs. per tree. The fertilizers were harrowed in or plowed down. An examination in the autumn of 1891 showed the following conditions:

| | | |
|---|---|---|
| Per cent of new cases on the controls | | 15.1 |
| Do | on S ½ of the treated plats (281 trees) | 23.1 |
| Do | on N ½ which received extra muriate (286 trees) | 29.8 |
| Average of the entire orchard. | | 19.4 |

The conclusions drawn from these experiments are that superphosphates and muriate of potash have no specific action in peach yellows, and that, if anything, the treatments here described favored rather than hindered the spread of the disease. [The substance of this paper will be printed in Bull. of Dep't of Agriculture.]

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HOW THE APPLICATION OF HOT WATER TO SEED INCREASES THE YIELD. By Prof. J. C. ARTHUR, LaFayette, Ind.

[ABSTRACT.]

THE use of hot water for preventing smut in wheat and oats has led to the discovery that when the seed of cereals is immersed for a few minutes in water at 125° F. and upward, the rate of growth and yield from such seed is greatly increased. It is found that this is not due to any change in the character of the seed coat by which it is enabled to absorb water more readily, or to the presence of extra water in the seed at the time of sowing. The paper details the experiments and evidence, which have led to the conclusion that the moist heat renders an additional amount of enzym available, which otherwise would only come into action slowly as the seed grew. This active ferment renders an unusual amount of starch soluble at the outset, and in consequence there is increased growth and final yield.

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NOTES ON MAIZE. By DR. GEORGE MACLOSKIE, PRINCETON, N. J.

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SPIKES OF WHEAT BEARING ABNORMAL SPIKELETS. By Prof. W. J. BEAL, Agricultural College, Mich.

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ADAPTATION OF SEEDS TO FACILITATE GERMINATION. By W. W. ROWLEE, Instructor in Botany, Cornell Univ., Ithaca, N. Y.

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NOTE ON THE YELLOW PITCH-PINE, PINUS RIGIDA MILLS, VAR. LUTEA, N. V. By Dr. W. A. KELLERMAN, Ohio State Univ., Columbus, Ohio.

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DO TERMITES CULTIVATE FUNGI? By O. F. COOKE, Clyde, Wayne Co., N. Y.

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NOTES ON DAUCUS CAROTA. By Prof. CHARLES W. HARGITT, Syracuse, N. Y.

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CONDITIONS THAT DETERMINE THE DISTRIBUTION OF BACTERIA IN THE WATER OF A RIVER. By Prof. JAMES H. STOLLER, Union College, Schenectady, N. Y.

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VARIATION IN NATIVE FERNS. By Rev. W. BEAUCHAMP, Baldwinsville, N. Y.

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SKETCH OF FLORA OF DEATH VALLEY, CALIFORNIA. By Prof. FREDERICK V. COVILLE, Dep't of Agriculture, Washington, D. C.

LIVE-FOR-EVER ERADICATED BY A FUNGOUS DISEASE. By Dr. D. F. FAIRCHILD, U. S. Dep't Agriculture, Washington, D. C.

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OTTO KUNZE'S CHANGES IN NOMENCLATURE OF NORTH AMERICAN GRASSES, By Dr. GEORGE VASEY, U. S. Dep't Agriculture, Washington, D. C.

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REVISED NOMENCLATURE OF THE ARBORESCENT FLORA OF THE UNITED STATES. By B. E. FERNOW AND G. B. SUDWORTH, U. S. Dep't of Agriculture, Washington, D. C.

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SHRINKAGE OF WOOD AS OBSERVED UNDER THE MICROSCOPE. By FILIBERT ROTH, Ann Arbor, Mich.

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PEZIZA SCLEROTIUM. By Prof. L. H. PAMMEL, State Agricultural College, Ames, Iowa.

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TEMPERATURE AND SOME OF ITS RELATIONS TO PLANT LIFE. By Prof. L. H. PAMMEL, State Agricultural College, Ames, Iowa.

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REPORT TO THE BIOLOGICAL SECTION OF THE A. A. A. S. ON THE AMERICAN TABLE AT NAPLES.

THE committee appointed at the Washington meeting to solicit subscriptions for the support of an American Table at the International Zoölogical station at Naples, Italy, respectfully submits the following report:
Subscriptions were obtained as follows:

| | |
|---|---|
| A. A. A. S. | $100.00 |
| Association of American Naturalists (Annual meeting, at Philadelphia in December, 1891), | 100.00 |
| University of Indiana, | 50.00 |
| Prof. C. O. Whitman, | 25.00 |
| Maj. Alex. Henry Davis of Syracuse, N. Y. | 225.00 |
| Total | $500.00 |

Upon application highly endorsed by Professor Whitman and others, Dr. E. B. Wilson, Adjunct Professor of Biology, Columbia Coll., N. Y., was granted the use of the table from Jan. 1st to July 1st, 1892. Professor Wilson worked upon the embryology of Annelida.

Upon application endorsed by Professor Brooks and Dr. H. L. Russell of Johns Hopkins University, the use of the table from Sept. 1, to Dec. 1, 1892, was granted to Dr. G. W. Field, A.B., Brown University, 1889, Ph.D., J. H. U., 1892.

Dr. Field has already started for Naples where he intends to study the phenomena of the regeneration of lost parts among Echinoderms.

Your committee has heard indirectly that an American lady zoölogist has recently made application direct to Gehemirath Dohrn for permission to work at the station and that the permission has been granted.

Dr. H. L. Russell, who occupied the Table from April 1, to July 4, 1891, has published the results of his investigations conducted at Naples in two articles:

"Untersuchungen über im Golf von Neapel lebende Bacterien (Zeitschrift für Hygiene und Infectionskrankheiten, Bd. XI, p. 165-206, Taf. XII u. XIII); Impfungsversuche mit Giard's pathogenem Leuchtbacillus (Centralblatt für Bakteriologie und Parasitenkunde, Bd. XI, p. 557-559).

Very general satisfaction has been expressed by American biologists upon the action of the A. A. A. S. last year, in taking the initiative for the support of an American table at the Naples station and several prominent investigators have expressed the hope that the Association will appoint a committee this year to collect the necessary money for the support of a table for the year 1893. Two biologists have already signified their willingness to subscribe for the table for 1893.

Your committee therefore respectfully recommends that the Biological Section of the A. A. A. S. petition the Council for a subscription for 1893, and that a committee be appointed to raise the balance necessary for the support of the table.

Respectfully submitted,

B. E. FERNOW, *Chairman.*
R. W. STILES, *Secretary.*

Washington, D. C., August 15, 1892.

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REPORT UPON THE PROPOSED BIOLOGICAL STATION AT JAMAICA. By ALBERT H. TUTTLE, University of Virginia, Charlottesville, Va.

THIS report is made to Section F for the purpose of calling attention to the movement now on foot for the establishment of a Station at some desirable point upon the island of Jamaica, to be known as "The Columbus Marine Biological Station." It is the intention of the promoters of the enterprise to make the Station international, but chiefly under English and American auspices, and steps have already been taken in England and America towards the accumulation of an adequate fund.

The advantages offered by such a Station to American biologists will be manifold. Among others may be mentioned the richness of the fauna and flora, both marine and terrestrial. Prof. Jas. D. Dana says of this, "I know of no place on either side of the northern Atlantic so well suited in this respect for a biological station:" Prof. W. K. Brooks, who has already spent several months at Jamaica, and who has made prolonged visits to nearly every point of importance along our coast and at several places in the West Indies, expresses himself equally strongly in favor of the proposed location. The opportunity which every naturalist desires to see something of tropic life can nowhere be afforded more advantageously. matic conditions are favorable to a marked degree, and the high mountains of the interior afford numerous pleasant places of resort when a change is desired from the heat of the coast. The island is well governed under English rule, and good sanitary conditions exist in the towns. The cost of living is small, and access from American ports is easy and not expensive, rendering it practicable for American investigators to spend successive summer vacations at the Station without great inconvenience or outlay.

It is certainly desirable that the American Association for the Advancement of Science should do all in its power to aid in the establishment and maintenance of the proposed Station: to this end it is suggested to this Section that it recommend to the Council of the Association the appointment of a committee to report at the next meeting upon a plan of coöperation, including the permanent establishment of a table at the Station, to be known as the American Association table.

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## REPORT OF COMMITTEE ON BIOLOGICAL NOMENCLATURE.

*Resolutions of the Australasian Association for the Advancement of Science concerning an International Committee on Biological Nomenclature.*

"1. That it is desirable to secure greater uniformity in Biological Nomenclature, especially in the department of Morphology.

2. That in order to secure such uniformity the following steps be taken: — (A) The appointment of an international committee to define terms of general importance, *e. g.*, terms common to Botany and Zoology, terms relating to position, etc.; (B) The preparation of an authoritative Historical Glossary of Biological Terms; (C) The systematic record of new terms in the various recording publications.

3. That copies of these resolutions be transmitted to the British and American Associations and to the Anatomische Gesellschaft."

In response to the above, the American Association for the Advancement of Science, at its Washington meeting (1891), appointed, on nomination by the Section of Biology, the undersigned committee. At the Rochester meeting of the Association the following report was submitted to the Section of Biology, the Executive Council of the Association, and to the Association in general session. It was unanimously adopted, and the Committee continued. The report is therefore the preliminary contribution of the American branch of the International Committee on Biological Nomenclature.

*Recommendations submitted by the Committee and unanimously adopted by the Association, Aug.* 22-23, 1892:

1. The committee suggest that the French and Italian biologists each be invited to appoint a branch committee to act with the others.

2. It seems to the committee that, for the real betterment of nomenclature, it is necessary first of all to arrive at some agreement as to the underlying principles that should govern biological terminology.

(See notes following concerning these principles.)

3. It is necessary, under (A) of the second resolution, first of all, to make some kind of a selection of terms that are to be so carefully defined. And in this selection the guide should be the underlying principles that are agreed upon concerning the character of the improved biological nomenclature. (See p. 232)

4. The carrying out of (B) of the second resolution would logically follow from (A).

In this "authoritative glossary" it is recommended that the Latin form be given as the major heading, the headings being given in alphabetical order as in an ordinary dictionary.

It would be of very great advantage to have the etymology of the word, the gender of the Latin form, if a substantive, and also the adjective and in some cases the adverbial form.

Following the Latin form should appear the Italian, French, German and English forms of the word, *i. e.*, *Paronyms*, with the gender, nominative singular and plural and the adjective form exactly as for the Latin.

If the principle of *Paronymy* were thus carried out, the glossary would be as easily usable by any one familiar with biology as would a general dictionary of his own language. If one takes the word *Biology*, for example, it would be seen how easily the steps given above could be carried out:

| | | | |
|---|---|---|---|
| BIOLOGIA, | Lat. s. f. | pl. biologiae, | adj. biologicus. |
| | Ital. La Biologia, | pl. le biologe, | adj. biologico. |
| | Fr. La Biologie, | pl. les biologies, | adj. biologique. |
| | Ger. Die Biologie, | pl. die Biologien, | adj. biologisch. |
| | Eng. Biology, | pl. biologies, | adj. biological. |

(Used in its most general sense this word would have no plural, but the plural form might be used as is that of Philosophy. The plural was added to illustrate the plan with this particular word in which the committee is especially interested. The word *Nomenclature* is nearly as good an example).

Following the Latin form with its Italian, French, German and English paronyms, it would be of great advantage to have exactly the same definition appear in the different languages, then each could assimilate the idea through the medium of his own language.

It might be well also to include in this glossary the more common vernacular equivalents for ease in discovering the proper technical words. In this case the vernacular equivalents should be given in alphabetical order with the Latin words and a reference made to the Latin form. (This method of a single vocabulary in alphabetical order is that of Foster's Medical Dictionary.)

5. (C). The committee urgently recommend that whenever a technical word is used for the first time, the author should give in a special note, (a), the Latin form, (b) the etymology, (c) the proper adopted form or paronym for his own language, with adjective, etc., when applicable, (d) as concise and precise a definition of the term as possible.

If a term is used in a new sense, attention should be called to it in a special note and the new sense carefully defined.

Finally the "recording publications" should, in giving the new words, give the Latin form as a major heading, and add the adjective, etc., and the various paronyms formed on established philological principles, an expert in biology as well as in philology in each language performing the work for that language. The definition should also be given in all the languages. In this way the compilation of future authoritative glossaries would be greatly simplified.

6. With reference to the unification of terms in botanical and zoölogical morphology it (second resolution (A) ) is certainly worthy the best efforts of the committee. The way was really opened by Schleiden and Schwann, and by calling the same substance in animals and plants by the same name, viz., Protoplasm (Sarcode of Dujardin, Protoplasm of Purkinje, von Mohl and Max Schultze). See the accompanying list of works on nomenclature.

*Underlying Principles to guide in the Selection of a Biological Terminology:*

The following are submitted by the committee for consideration and adoption:

1. That the names of organs and parts, and the terms indicating position and direction should be single, designatory words (*Mononyms*) so far as possible, rather than descriptive phrases. All who have considered the subject of Nomenclature have advocated this as one of the guiding principles. This would exclude the use of the names of men as applied to parts of the body, as, for example, *Malpighian corpuscles* for the renal glomeruli and the lymph follicles of the spleen.

2. That morphological terms should be etymologically correct, and so far as possible derived from Greek or Latin, and that each term should have a Latin form.

That all terms should have a Latin form, regardless of their derivation, has been almost universally advocated. From the nature of the language, Greek has been the great storehouse from which science has drawn its technical terms; it is by far the most satisfactory source for precise terms.

3. That terms relating to position and direction in an organism should be INTRINSIC and not EXTRINSIC, that is, should refer to the organism itself rather than to the external world.

The desirability of using an intrinsic terminology for direction and position in an organism, was very clearly pointed out by Chaussier (1789) by Barclay (1803), and by numerous writers since. The actual employment of an intrinsic terminology, to a greater or less extent is illustrated in all the great anatomical and morphological works as one may see by consulting the Anatomie of Bichat (1801); that of Henle (1873); the works of Owen, 1846, 1868, that of Key and Retzius, and the Monographs on Embryological, Morphological or Physiological subjects appearing in the Philosophical and other Transactions and in the great scientific periodicals.

The suggestion of the committee is then that this most desirable tendency in the direction of the use of intrinsic terms be encouraged, and the systematic use of such terms be urged.

4. It is further recommended that each of the technical words have, in addition to its proper Latin form, a form which shall make it conform to the genius of the various languages, *i. e.*, that a paronym be made for each technical word. In many cases the Latin form is adopted without change in some of the languages, or one or more languages might make some slight change in spelling or termination to make it more readily conform to the language adopting it. The word Biology is a good example. The point is simply that the technical words of Biology shall have in addition to the Latin form one making them a part of the language adopting them and so slightly changed that any one familiar with the classical form would recognize the word instantly in either Italian, French, German, or English. If this principle of *Paronymization* were carried out systematically the intelligibility of scientific writing would be greatly increased. Naturally the Romance languages afford the best examples, but numerous examples are found in English and also in German.

The committee recommend that biologists in the future consciously and systematically adopt a plan of terminology which has been practised unconsciously and unsystematically, but with great help in intelligibility, in all the arts and sciences.

5. Perhaps no stronger plea could be made for this principle of paronymy, this making the technical language of science also the language of the people, than the following quotation from Asa Gray:—"Greatly to its advantage, English botanical terminology has adopted and incorporated terms from the Latin and Greek, with slight changes, not obscuring the identity, thus securing all their precision and rendering the simple botanical Latin of descriptions easy of acquisition by the English student." Structural Botany, § 738, p. 360.

6. The committee consider it both proper and wise to recognize the labors of the Committee on Anatomical Nomenclature of this Association, as given in their report for 1889 and 1890. (See following page.)

*III. American Association for the Advancement of Science. Extract from the Proceedings*, 1890, *Vol. xxxix, p.* 20.

"*Fourth Preliminary Report of the Committee on Anatomical Nomenclature, with special reference to the Brain.*"

"The committee recommend:

1. That the adjectives *dorsal* and *ventral* be employed in place of posterior and anterior as commonly used in human anatomy, and in place of upper and lower as sometimes used in comparative anatomy.

2. That the cornua of the spinal cord, and the spinal nerve-roots, be designated as *dorsal* and *ventral* rather than as posterior and anterior.

3. That the costiferous vertebræ be called *thoracic* rather than dorsal.

4. That the hippocampus minor be called *calcar*; the hippocampus major, *hippocampus*; the pons Varolii, *pons*; the insula Reilii, *insula*; pia mater and dura mater, respectively *pia* and *dura*."

In the report of 1889 (Proceedings, Vol. xxxviii), p. 26, the point agreed upon by the committee was: "The advantages, other things being equal, of *mononyms* (single word terms) over *polyonyms* (terms consisting of two or more words"). See p. 232.

### LIST OF THE MOST IMPORTANT WORKS ON NOMENCLATURE.

1789. Chaussier, Fr.: Exposition sommaire des muscles du corps humain, suivant de la classification et de la nomenclature methodique adoptée au cours public d'anatomie de Dijon.

Chaussier makes some most excellent remarks on the fundamental principles of terminology; his application of the principles was not particularly happy, however.

1803. Barclay, John: A new Anatomical Nomenclature, relating to terms which are expressive of position and aspect in the animal system.

The work of Barclay is one of the great landmarks in Anatomical Nomenclature.

1846. Owen, Richard: Archetype and Homologies of the Vertebrate Skeleton; also the Anatomy of Vertebrates, 1861-1868.

1877. Pye-Smith: Suggestions on some points of Anatomical Nomenclature. Journal of Anat. and Physiol., 1877, pp. 154-175.

General suggestions excellent; the specific recommendations on histological nomenclature not so acceptable at present.

1889. Leidy, Joseph: Human Anatomy. See B. G. Wilder's paper in the Phila. Medical News, Dec. 19, 1891.

1871-1891. Wilder, Burt G.; Various papers on Anatomical Nomenclature.

The latest in the Medical News and the preceding one in the Reference Hand-Book of the Medical Sciences, may be submitted as representing an epitome of the whole subject, with suggestions for future progress.

1891. Parker, T. J.: On Nomenclature. Nature, Nov. 19, 1891, pp. 68-69.

The subject is discussed somewhat with reference to the work of the International Committee.

1889. Congrès International de Zoölogie; Compte-Rendu des Séances.

A paper by Voldemar Wagner of Moscow, discusses whether or not scientific names should be literally translated into the modern languages, p. 431. On page 425 the same author discusses histological nomenclature.

This Vol. contains a very extended discussion of the Nomenclature of Zoölogy and Botany, *i. e.*, the names of species, etc.

See also the leaflet by the Anatomische Gesellschaft, giving the principles on which that society thinks improvement can be made. See also the remarks by Kölliker as President of the Anat. Gesellschaft, at the last meeting, in Verhandlungen der Anat. Gesellschaft auf der fünfte Versammelung, pp. 3, 4 and 5; also in Biologisches Centralblatt, 1892, pp. 34–36.

W. Krause also read a paper upon the subject at the meeting of the British Association last year. See Internatl. Monatschrift für Anat. und Physiol., Feb. 1892.

G. L. Goodale: Terminology.

See also list at the end of article, Anatomical Terminology, in the Reference Hand-Book of the Medical Sciences, Vol. viii, p. 536.

George L. Goodale,
Harvard University, Cambridge, Mass.
John M. Coulter,
Indiana State University, Bloomington, Indiana.
Theodore Gill,
Smithsonian Institution, Washington, D. C.
Charles S. Minot,
Harvard Medical School, Boston, Mass.
Simon H. Gage,
Cornell University, Ithaca, N. Y.

## SECTION H.

# ANTHROPOLOGY.

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Charles P. Hart, Wyoming, O.

*Members of Sub-committee on Nominations.*

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# ADDRESS

BY

# W. H. HOLMES,

VICE-PRESIDENT, SECTION H.

## *EVOLUTION OF THE ÆSTHETIC.*

The anthropological field is a wide and most diversified one, offering countless themes well fitted for presentation before this annual gathering of section H. Prehistoric anthropology in America, the department in which I with many others have chosen to labor, is an especially fascinating branch of the work, a field which opens out to the right and left into most enchanting and seemingly endless vistas of the unknown, tempting the investigator to ever-renewed effort. So numerous and so attractive are the pathways into unexplored regions that the mind of the enthusiast—and we are all enthusiasts—is fairly dazed with the allurements, and the desire to do and to accomplish fairly outruns the capacity to execute. Each day as we hasten on, thinking to have reached the end of some particular by-way of investigation, new fields open to view of which we have not even dreamed.

To-day I shall turn aside from the well-trodden ground—the study of the ordinary arts, industries, habits, customs and institutions of mankind—to take a hasty glance into a comparatively new field, the study of the non-essential arts of man; from the substantial phases of energy and thought I turn to the flowers of thought, to the realm of the æsthetic, to that strange land of the imagination where nothing is seen but for the pleasure of seeing, where nothing is heard but for the pleasure of hearing, and where nothing is thought but for the pleasure of thinking. But it is not a pleasure voyage upon which I propose to embark. You will not be asked to luxuriate in the colors and fragrance of the æsthetic kingdom or in the seductive observation of form and motion, but to study the phenomena of the beautiful as the botanist studies the real flowers of the fields by plucking them and picking them to pieces, striving thus to lay open the secrets of their existence.

The science of the beautiful must deal with actual phenomena, with facts as hard, with principles as fixed and laws as inflexible as do the sciences of biology and physics. But in the past, on account of the obscurity and the complexity of the phenomena, the subject has been left greatly in the hands of the metaphysician who has woven about it a dense and very subtle web of transcendental fancy. It has been sought to determine the precise nature of beauty as an abstract quality, to discover those particular attributes of objects, of works of art, of faces and of figures, that make them beautiful and distinguish them from other things thought to be ugly. It was conceived that this quality was fixed and uniform and was the only source of those subtle pleasures of the mind called æsthetic. The war of words has been kept up for generations and the battle still goes on being neither lost nor won.

There are also very intricate questions arising in the discussion of the subjective side of æsthetics as to the exact nature of the sensations and perceptions that take part in the recognition of beauty as well as of the related and little studied fields of the sublime and the ridiculous. For the present I shall pass over these more obscure and involved subjects, relying on the hope that when the simple observable phenomena of the æsthetic, subjective and objective, have been fully observed, studied and classified, as the naturalist deals with the phenomena of biology, the more obscure questions so often asked, may, in a great measure, solve themselves.

But how shall we arrive at a definite and adequate idea of the nature and extent of the field covered by the æsthetic? We have seldom paused in our busy careers to dwell on a subject so obscure. Although exercising the faculty of taste upon all sorts of subjects from day to day throughout life the functions are so necessary and habitual that they are hardly more noticed than the facts that we breathe or see or think. We therefore totally fail to realize how much time and thought are given to æsthetic considerations and what a very large place they really fill in the thoughts and activities of the world. This would come home to us if by some sudden change in the constitution of things all that is æsthetic should be rudely torn from us and banished from the world. The utter desolation of such a situation is, however, quite inconceivable until we are brought to fully realize the vast extent of the field occupied by the æsthetic. To make this clear, let us suppose that some dire disease should dull and destroy our perceptions of the beautiful. Imagination can hardly picture the result. A world of useless and utterly nonsensical things would be found encumbering our existence, and these would necessarily be cast away. First, and perhaps most striking of all, the fine arts would fall into disuse. Painting, sculpture, architecture, poetry, music, romance, the drama, and landscape gardening, would disappear utterly, leaving blanks of inconceivable magnitude. No picture would grace the wall of gallery or dwelling. Temples and halls of history would be without statuary, and books would be without illustrations save of diagramatic or recording kinds. Architecture would degenerate into the merest house building, into the construction of boxes for dwelling and business and storage, without such features as unnecessary projections, mouldings, carving, painting, frescoing, hangings, carpeting and other elements serving to give pleasure, other than of the purely creature kind. Churches would be but the plainest barns without archways, and columns, and steeples, and towers, and stained glass; and the organ, and the choir, and the singing of songs, would be as though they had never been. All artists, sculptors, architects, poets, authors, composers, and dramatists, and all the multitude that depend upon them, decorators, engravers, carvers, musicians, actors, book makers, etc., manufacturers of all that pertain to the polite arts, and all merchants who deal in æsthetic things would turn to other callings; and the ships and the railways that transport the products of æsthetic industry, silks, and rugs, and laces, and all ornamental goods, and furniture, and tiles, and paints, and dyes, and porcelains, and brasses, and æsthetic things without end, would cease to plow the sea or girdle the land. The range of human livelihood would be reduced to a dangerous degree, and existence, a burden without art, would be overwhelmed with poverty and distress.

And what would be the effect upon men and women and society? Extract from dress every element of designed beauty and from the person take away every ornament. Imagine the loss of every perception of delicacy of form and grace of movement, all appreciation of proportion, and texture, and complexion of skin; the most perfect woman would not be more attractive than the haggard duenna, and society without physical graces and without music and poetry and the charm of æsthetic speech would be a barren formality indeed. Still more, nature would cease to exercise its varied charms. The sea and the sky, the glory of sunrise and sunset, the freshness of spring, the fullness of summer and the glories of the whole kingdom of bloom would cease to be thought of save as the merest commonplaces. Religion would be divested of the charms of the imagination and the shining wings of angels, the glistening of the jewelled gates and even the effulgence of the face of the Almighty itself would be a mockery. Take away the æsthetic sense from life and all the pleasure supplied by it, and existence, as viewed from our present point of view would be ineffably stupid. Take away that which is the mainstay and the essence of culture and civilization would hardly stand the shock.

It may possibly appear that in thus attempting to convey a vivid notion of the nature and extent of the æsthetic field, that the picture has been overdrawn, that too much has been included under the term æsthetic. In its origin the term covered a field wider than is here indicated, but even if this were not the case the mere name should not stand in the way of a proper assemblage of the phenomena concerned. The scientific discussion of the subject requires that everything pertaining to the existence of the æsthetic sense, to the exercise of taste, and all that pertains to its genesis and history should receive consideration. The phenomena of taste are not the accidents of a particular period of culture; they did not spring into existence full fledged and without ancestry, thus defying the laws of nature. They had their inception in the experiences of the infant race. Certain powers and capacities of the mind and certain groups of elements and features of nature and art, acting and reacting one upon the other, gradually led to the development of a group of results represented in their most typical phases by what are known as the fine arts; these are but the ripened results, the fruits of countless ages of experience. The scientific examination of a group of plants is not complete when the flowers and fruit have alone been studied. There are the leaves and branches and roots and trunk and their structure and functions. More than this, we are not satisfied until the history of the group and the family is examined and we have traced the course of evolution back beyond the limits of the botanic field. The scientific study of a nation consists not in the examination of that nation as a perfected unit of society but involves its remotest ancestry, extending beyond the human boundaries to creatures and to organisms not yet freely and fully recognized as related to the human family.

The creations of art are growths as are the products of nature, and are subject to the same inexorable laws of genesis and evolution. The great painting of to-day, gracing the wall of dwelling or gallery, had its prototype in the tattoo marks of some primeval man or in the scrawls that embellished his simple utensils. The masterpiece of the sculptor's chisel, now occupying a niche in some temple or monumental structure was represented in ages past by the misshapen image of clay attached as a charm to his person or to some article of use. The great poem of to-day bound in vellum and burnished gold is but an elaboration of the weird story of the unlettered savage, and the symphony that now casts its spell over the world was in that long ago the song of the savage who howled in imitation of the wind or the wild beast or kept time to his fantastic and never-ending dances. This relationship in genesis between the high and the low, the simple and the complex, implies a relationship between the lowest and the highest expressions of the arts of taste existing side by side at any given period. All represent feelings, emotions, thoughts lifted above the plane of the essential, and expressed by energies not necessarily expended in the mere struggle for existence. We may therefore include in the scientific discussion of the subject the widest possible range of phenomena. The field is thus a vast one, and it is important in this brief sketch to settle upon a method of procedure that will be extremely simple and at the same time give a comprehensive notion of the place of æsthetics in science and in human history.

It is plain from the nature of the field as just outlined, that the question is one of evolution. The examination of the present phenomena is but a glance at the surface of a subject, the history of which is interwoven with the history of man from beginnings so small and times so remote that our sight grows dim in the attempt to trace them. Let us then endeavor first to place the æsthetic field with reference to the whole field of human life and achievement. Let us begin with some simple unit of the subject as for example the history of the individual. Physically, man begins at zero and develops through the fœtal stage to birth and thence to full maturity and the climax of vigor and power. Mentally, there is a like advance from the initiatory step at birth to the prime of life. At first the thread of thought is exceedingly slender, but little by little it is strengthened by experience and observation supplemented by instruction. In youth it grows strong and in maturity acquires enormous expansion. Now if we take any one of the departments of life depending upon the physical or mental constitution and capacities of man, the same initiatory and progressive stages will necessarily be observed. The æsthetic idea first manifests itself in early childhood, at exactly what period no one can say, and advances with a rapidity varying with the conditions of existence to which the individual is subjected. The physical evolution of the individual may be illustrated by the space included between two diverging lines as in diagram A, Fig. 1. The mental evolution associated with it may be expressed by similar lines, B, representing narrow or wide expansion as the case may be. The opening of these lines at the right represents the full mentality—the whole range of feelings, emotions and thoughts at the prime of life. The æsthetic department of these mentalities will be included within the space allotted to mind, as indicated by the dotted lines. It begins later and cannot at any period occupy the whole space, but may occupy a large percentage of the mental range in highly cultured individuals or remain almost a simple line throughout life in the unlettered or sordid.

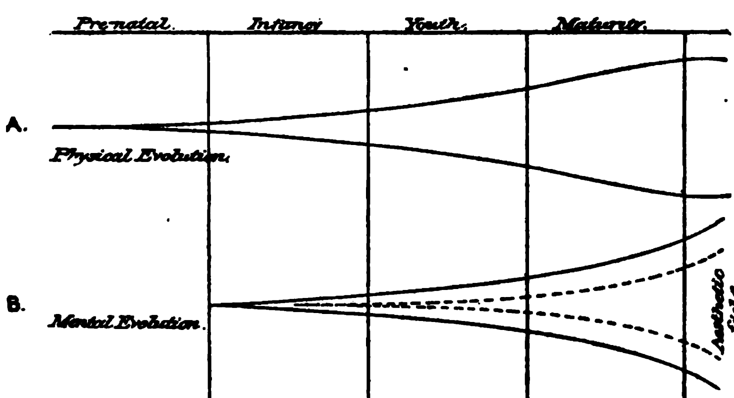


FIG. 1. Diagram illustrating physical and mental evolution of the individual.

A brief outline of the æsthetics of the individnal may be given. The child is powerless to express conceptions of an æsthetic kind before the acquirement of speech and before he is taught the terms necessary to expression, but there can be little doubt that the emotions of very young children partake of æsthetic qualities and that pleasure taken in a face, a bright object or a toy is closely akin to the pleasure derived by their elders from faces and pictures and poetic thoughts. With respect to these things we can hardly assume to do more than to surmise that out of the plexus of appreciations and likes of childhood, and the half-formed æsthetic conceptions of youth come the more highly specialized mentations of maturity, resulting in special æsthetic pursuits and in the production of various super-utilitarian works of art.

If we accept the theory that play—the aimless activities of childhood— is a form of the æsthetic, then the diagram of individual æsthetic progress will need to be changed; for the play of youth is more absorbing and all-prevading than the æsthetic activities of manhood. Although the relation of play to æsthetic art pointed out by Schiller and elaborated by Spencer certainly exists, and therefore deserves careful consideration, it is apparent that many of our æsthetic perceptions pass back naturally and completely into the sensual pleasures and gratifications of past ages, into the loving consideration of things pleasurable and constantly enjoyable throughout long periods of development.

But passing over these and many other points of great interest let us turn from the æsthetic history of the individual to that of the nation, hoping thus to arrive at some conception of that of the race. The evolution of a nation physically and mentally may be expressed by the same expanding lines as with the individual. The highest æsthetic stage of a nation is reached through a long series of lower stages beginning at the initial point and advancing with a movement more or less gradual as the conditions of existence favor or interfere with the normal progressive tendencies. In studying the individual we may resort to the combining of observations upon several individuals at different stages of development, one serving to teach us of youth, another of maturity and another of old age. The periods of nations are longer and the composite method of study becomes thus a measure of necessity. There is every reason for believing that the expanding lines express correctly the physical and mental growth of nations as fully as they do that of individuals, so that I will not dwell upon the matter further than to show that in a measure the composite study of national histories brings out the history of the race.

Here is a nation, a European one we will say, standing at the very top of the scale of culture, whose history is known for a thousand years. When first known to the historian this nation was in a barbarous stage and the records show a gradual advance to its present state. The diagram of its progress would be expressed as in A, Fig. 2.

Here is another nation, say an Asiatic one, now passing the confines of barbarism and entering the realm of civilization. Its history is known for a thousand years as diagramed in B. Still another nation has, in the short period of its recorded history, passed

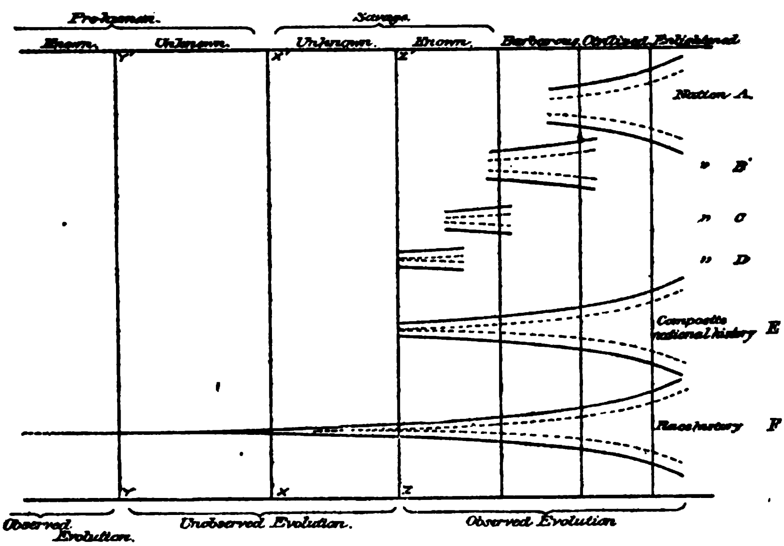


FIG. 2. Diagram illustrating national and race culture evolution.

from the savage into the barbarous period, and diagram C expresses its observed development. Take again the most primitive people known to science and its diagram is confined to the earliest-known stages of savagery, as in D. This series represents all that is known of the history of man, and the diagrams combined as in E express connectedly this history and at the same time record the known history of the race, F.

Now the various activities of man fall within the limitations of this scheme. Singling out the æsthetic we see, as indicated by the dotted lines, that it has developed as have the rest from small beginnings and that we can take up the threads of evolution at the base of the ladder and follow them up through their development and differentiation to the highest points reached; or that, reversing this order, we may begin with the fully-developed phenomena of to-day, represented by the fine arts, and pass back step by step through the ages to the lowest-observed savage state. We find, however, when we examine the stage of progress represented by our lowest tribes, that we are not yet at the true base of the ladder, that the beginning of things is still far beyond. There must have been a pre-savage state of society and we are compelled to prolong the converging lines of the diagram indefinitely and to conclude that the pre-savage state was in the beginning a pre-human state. It is within these initial stages of progress that we must look for the roots, the inceptive stages of the great groups of phenomena pertaining to advanced humanity. Our notions of these initial stages must be derived from inferences as to the natural order of things and from analogies furnished by the living lower order of creatures. It is conceded by most biologists that traces of appreciation, bordering closely on what we designate the æsthetic, are observed in many species of animals, and pre-human man, furnished with all the senses with which we are endowed, must have had keen impressions of pleasure of like quality through the exercise of sight and hearing and smell and taste and touch. In this period the foundations must have been laid for all the higher subjective phenomena of to-day; and even the shaping arts, afterwards the stems upon which the æsthetic vine grew and developed, had here their remotest beginnings. We cannot permit it to be assumed that the pre-human man was inferior at all stages of his existence to the birds and ants, the squirrels and the apes, who construct dwellings and invent devices to secure food and to escape danger. If it be allowed that the bower bird bedecks her dwelling with bright objects from an appreciation of their decorative effect, it may be fairly assumed that other creatures may have developed like tastes in low stages of intellectual development. At any rate it seems highly probable that when the mile-post of progress, separating the pre-human from the human stages, x x′ of the diagram, was reached by the race, many strands of æsthetic thought were already spun. They were as yet no doubt exceedingly attenuated and completely involved with other purely practical threads of progress from which, long afterwards, they were destined to be differentiated and divorced.

At the base of our historical ladder we encounter the most primitive human culture known, the most lowly races coming within the range of modern observation; but we find that these lowly savages are already far advanced upon the highway of culture and are exercising taste upon a multitude of subjects. So fully have the threads of the æsthetic enlarged and differentiated that we recognize the separate strands of painting, sculpture, music, and poetry. We may well pause in astonishment when we first come to observe this fact and to realize the brevity of the period, the shortness of the step, that separates our culture of to-day from that of the lowest tribes of which we have knowledge, and recognize the vastness of that period of culture progress that precedes the savage state extending indefinitely beyond our ken. Prolong therefore the initial periods of existence and trace the threads of culture back and still back into the unknown.

The student of evolution has the privilege of observing two great periods of progress and development in sentient creatures, one beginning with the lowest living forms and ending with the highest apes, say at Y in the diagram, the interspace being filled to a greater or less degree by very numerous creatures of varying grades of capacities and acquirements; the other beginning with the lowest known human being, say at Z, and ending with the highest type of man. Between these two great groups there is an enormous gap, Y to Z, across which the human race alone, so far as we know, has passed, and the history of that passing is only to be inferred from what we know of what went before and what followed and from such meager and unsatisfactory evidence as geology furnishes to the archæologist. Within this unobserved period, one step of progress was made that, according to many thinkers, is the most important step known to the science of man. That step was across the so-called chasm that separates man from beast, that separates the realm of instinct from the realm of reason, the age of nature from the age of art (X X′). All that was done anterior to that step was the work of nature; all that was done after that step is attributed to art. This distinction is no doubt an important one, but its employment is open to the objection that there can really be no line of demarkation separating the phenomena of one stage of evolution from those of another and there is danger of the change being thought of as a definite and comparatively restricted episode, as marking a complete ending of one phase of existence, and as being a datum point from which to begin the study of the succeeding phase. The fact is that the change from the domain of instinct to that of reason, from unconscious to conscious activity is a most gradual one, covering a long period of evolution, and it may be safely maintained that our race is not yet fully above the mere animal stage of art, for men still execute much that goes to make up art and especially æsthetic art, with a spontaneity

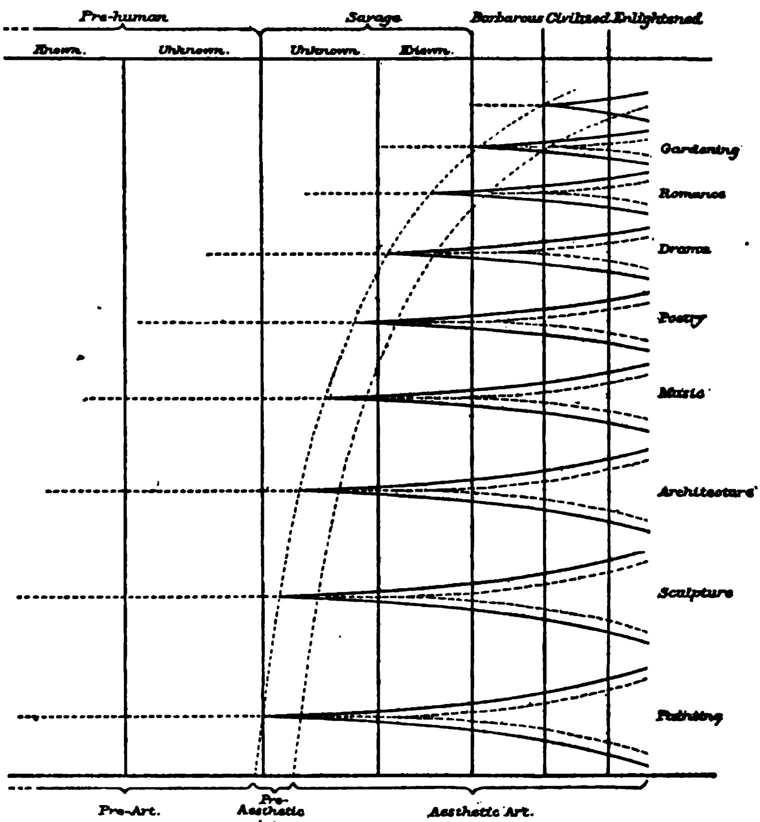


FIG. 3. Diagram giving tentative order of æsthetic groups.

resembling closely that of the instinctive period. The period of transition from the instinctive to the purely intellectual status of human mentations and activities may therefore be indicated in the diagram as beginning at x x′ and continuing to the present time. On crossing the frontier line the first steps taken in conscious art would be ill-defined and restricted to the narrowest bounds. As age after age passed new groups of art would come into existence and present conditions would finally be reached. The first step in æsthetic art might not be taken until long after the passage of the line separating unconscious from conscious art; but as in useful art the æsthetic groups would follow each other in a slowly moving procession covering the whole range of periods down to the present. These features of æsthetic growth are indicated in the diagram, Fig. 3.

There appears for my present purpose no more effective way of conveying a notion of the course followed by æsthetic development from the earliest to the latest stages of human history than that of taking up and considering separately the several branches of æsthetic art. The order in which they should be considered is not fully determined. That order should agree if possible with the order of their genesis, since they are in a measure interdependent and arise by differentiation, but this order is as yet somewhat a matter of conjecture. It would seem that since man's progress has been marked by a succession of social conditions and that the arts are deeply concerned in the evolution of these conditions, that they should be placed in an order based upon their relations with social conditions. The social group begins in the lowest state with the individual or includes the man and his family and extends finally in civilization to include large portions of the human family. The earliest arts would be the most completely egotistic, that is to say those most nearly concerned with the individual, and more especially with the person of the individual. First, among these would be painting. The latest arts would be those arising from advanced social conditions, as romance and landscape gardening. Tentatively, therefore, I will place the commonly recognized æsthetic arts in the following order: painting, sculpture, architecture, music, poetry, the drama, romance and landscape gardening.

In the pre-human and early savage ages, color must have been an important element of man's environment and the color sense was probably developed at an early day with all creatures gifted with sight. Darwin points out the extraordinary changes in color brought about in the hair and skins of animals and in the plumage of birds apparently by desires to attract, and as a means of attracting the opposite sex. In perceiving and distinguishing things in nature, the recognition of which was important to the preservation of life, the color sense was of the greatest consequence, and I am inclined to believe that the earliest efforts made by man to modify anything, to create anything not intended to serve directly the ordinary purposes of life, would be in the direction of making, by means of color, changes in personal appearance to effect men, women or animals by attracting, repelling, or deceiving them. If first employed to attract the opposite sex, as may readily have been the case, then these initial steps were in the direct line of the æsthetic, serving to effect pleasurably the emotions of men. Among the lower tribes there are no more universal arts than those of painting and tattooing the skin and these are always associated with the appending of ornaments and with a great variety of personal mutilations, all closely akin to painting in effect, and all in the main intended to increase attractiveness.

The term painting includes a very wide range of art phenomena. As ordinarily employed it refers to the various forms of expression in color in which the brush is the means of execution, but as an æsthetic species it includes all expression by means of color, whether in outline, in solid color, in stains and dyes, in weaving and in mosaic, no matter whether executed by means of brushes, dyes, combination of parts, or by means of chemical processes. I prefer to present this art first for the reason that, as already indicated, it appears to be more closely associated with the person of man in the initial stages of culture than any other of the arts expressive of æsthetic notions.

Personal embellishment was so much a part of the life of the savage that the practice of applying decorations would readily be transferred from the person to objects and articles of use near the person, as to his utensils, weapons and dwellings. These were colored to match his personal colors, or were marked in imitation of his tattoo marks; they were beautified to heighten his own claims to attractiveness. Graphic materials were everywhere obtainable, blood, juices of plants and fruits, charcoal, ochres, and colored clays needed hardly to be sought. The fingers were the first brush, and the human skin the first canvas. These practices undoubtedly long preceded the pictographic stages of painting and constituted the earliest objective phenomena of the graphic arts. Colorations and markings of the skin were not necessarily graphic in the sense that pictures are graphic but they may still have been representative of creatures or things and hence significant or symbolic. Picture making would imply very considerable art ability and a comparatively high social condition, and pictography and mythologic painting are far removed from the base of the æsthetic ladder. Pictography needed to do no more in the way of delineation than to make itself understood, and its presentations no sooner became intelligible by virtue of their truth to nature than they began to depart again from truth and under a number of conventionalizing agencies, to assume formal or simplified shapes which became hieroglyphics and letters retaining a minimum of æsthetic qualities and possibilities.

In all his arts man sought the assistance of the personified creatures of mythology, and delineations of the gods were applied to his person, to utensils, implements, weapons, and dwellings. These delineations were subjected to strong conventionalizing influences and assumed forms imposed by the arts in which they were employed. Thus in pottery the delineations were limited to the small and often narrow spaces of the vessel. In the narrow spaces the forms descended to complete formality, uniting with the plain geometric figures otherwise derived. In the wider spaces they were considerably elaborated, depicting in bright colors and with much vigor, personages and scenes derived from mythology. Greek ceramics afford a fine example of this class of work, and the Japanese art of to-day illustrates the widest scope of painting within the limits of this art.

From painting upon the human skin, on robes and bark, the textile art acquired a heritage of delineation which took remarkable forms of convention due to the geometric combinations of the web and woof. By the use of dyes, rich and varied effects of color were obtained, and embroidery and tapestry produced magnificent results, the subjects being derived at first from mythology, and later among cultured nations, from history, romance and real life.

House building developing into architecture adopted the painter's art and sheltered, encouraged and developed it, not only making the existence of ceramics and woven fabrics possible, but offering the choice spaces upon its walls, and columns, and cornices, and ceilings to the brush of the painter. In the decoration of temples, cathedrals and palaces, painting had its greatest opportunity and has freed itself from the fetters of utilitarian art, achieving approximately the goal of purely æsthetic or ideal art.

It is thus seen that several of the arts, useful and æsthetic, have nurtured and developed threads of the painter's art. These threads contributed each its share to the total result; rising out of their various genetic channels, they have combined to make up the æsthetic species painting. A much simplified diagram illustrating the inception of this æsthetic group and its progress upward through the ages is placed at the base of the series given in fig. 3. The æsthetic portion of the art of painting is exceptionally large, covering indeed nearly the entire field and its inception reaches back very far toward the art frontier or limit, x x′.

Next to painting I place *sculpture*, the arrangement being only tentative, however, and subject to change as evidence accrues to warrant it. In its initial stages this art group is closely associated with painting and later is much involved with architecture. The latter association has been kept up to a large extent throughout its history. With the first use of an implement by the creature man entering gradually upon the human stage, sculpture was brought into the circle of the arts. Man cannot use any utensil, implement, or weapon without subjecting it in its use to sculptural action, and these changes of form in use must in time have suggested and led to intentional changes, to shaping by abrasion, beating, scraping, cutting and grinding, and these are all acts of sculpture. As an æsthetic art, sculpture probably followed painting somewhat closely through the use of articles appended to the person for purposes of embellishment, these articles being subjected to modification of sculptural kind to increase their beauty or convenience of use. When man advanced to the stage in which he symbolized men, animals and the unknown powers of nature and selected representatives of these after the nature of fetiches and charms, there opened a new field for the shaping art and mythology came very largely to furnish the subjects for this art.

Sculpture includes a wide range of phenomena taking a leading place in architecture, in ceramics and in many branches of industry employing decorative variations of solid materials. It must indeed even go beyond solid materials, so as to cover all of those art forms included under the term draping, as in costume and house furnishing, unless that department of the phenomena of taste be allowed to occupy an independent, coördinate place among the æsthetic arts. Its root must run far back into the pre-human period. As an art it may be assumed to begin in the earliest savagery and as an æsthetic art only a little farther on.

*Architecture* is made to follow sculpture, not that it is necessarily younger in its inception, for the root of the builder's art, the primal stem of architecture goes indefinitely back as does that of sculpture into the pre-human darkness, but because it was probably later in taking its place as a human art, being less egoistic and hence awaiting the development of somewhat advanced social stages to begin its career as an æsthetic art. It is placed third in the diagram.

Architecture deals essentially with construction; the germ is in house building, and as its scope widens it differentiates into sacred architecture, secular architecture and their subdivisions.

*Music* would at first glance seem to be one of the most primal of the arts, since nature is so full of musical sounds, and man, furnished with a voice and possessing decided imitative tendencies would apparently become a musical animal before he became man, but vocalization is not reckoned music, and the voice may be employed constantly and in a wide range of uses without producing what we call music. The essence of music is said to consist not in sweet sound, but in rhythm, melody, harmony, and symphony as pointed out by Major Powell, and is thus not a human art until men have advanced to the social stage where play and dance give birth to rhythm, sweet sounds not being essential until still greater advance is made and melody is understood. It would seem, however, that if we consider this group to comprise the æsthetics of sound rather than of that portion of acoustic phenomena included under the term music that its position in the diagram might have to be changed, for the use of vocalization to influence and charm men and creatures, and the recognition by men and creatures of æsthetic qualities in these vocalizations must have begun at an early date.

Following music come *poetry*, *drama* and *romance*, and, lastly, unless we introduce such groups as *dancing*, *draping*, *taxidermy*, *pyrotechnics*, etc., comes *landscape gardening*. These are placed upon the diagram to indicate approximately their places in the scheme of æsthetic evolution, the later pertaining only to the civilized and enlightened stages and having no well marked inceptive stage in the earlier phases of culture. But I will not attempt the further elaboration of details since my desire was only to map out the subject and to give a somewhat comprehensive idea of the nature and extent of the æsthetic. The diagrams will serve this purpose more effectually than words. Together, or one after another in genetic sequence, the several branches of æsthetic art sprang into existence. By passing up through the scale of cultural stages from savagery to enlightenment we see that each succeeding period has a larger share of art and a correspondingly larger share of the æsthetic, each stage being prophetic of the succeeding stage. It will be observed that the last stage—that upon which the foremost nations of the world are now entering—the enlightened—is also necessarily prophetic of a still more advanced stage; and by adding to the number of æsthetic groups those yet to be conceived and prolonging the expanding lines of each group indefinitely, we are led to comprehend the true relations of the striking present to the marvelous future and to form some notion of the magnificent sum total of the æsthetic that future generations will be privileged to enjoy.

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# PAPERS READ.

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PROPOSED CLASSIFICATION AND INTERNATIONAL NOMENCLATURE OF THE ANTHROPOLOGIC SCIENCES. By Dr. D. G. BRINTON, Media, Pa.

THE author proposes the following classification and nomenclature of the anthropologic sciences:—

## ANTHROPOLOGY.

I SOMATOLOGY.—Physical and Experimental Anthropology.
II. ETHNOLOGY.—Historic and Analytic Anthropology.
III. ETHNOGRAPHY.—Geographic and Descriptive Anthropology.
IV. ARCHÆOLOGY.—Prehistoric and Reconstructive Anthropology.

### I. SOMATOLOGY.

1. **Internal Somatology:**—Osteology, craniology, prosopology, myology, splanchnology.

2. **External Somatology:**—Anthropometry, color, hair, canons of proportion, physical beauty.

3. **Psychology:**—Experimental and practical, sensation, rates of nervous impulse, brain and nerve action.

4. **Developmental and Comparative Somatology:**— Embryology, heredity, teratology, human biology, evolution, anatomy of anthropoids, ethnic anatomy and physiology, comparative nosology and medical geography, fertility and sterility, racial pathology, criminal anthropology, vital statistics, anatomical classification of races.

### II. ETHNOLOGY.

1. **Sociology:**—Systems of government and the social contract, laws and ethical standards, the marriage relations and rules of consanguinity and descent, social classes and institutions, international relations (war, commerce and colonization).

2. **Technology** :—The Utilitarian Arts, as tool-making, ceramics, architecture, agriculture, means of transportation, clothing, weights and measures, media of exchange; the Esthetic Arts—music, drawing, painting, sculpture, decoration, games, cookery, perfumery.

3. **Religion:**—Psychological origin and development; personal, family, tribal and world religions; animism, fetichism, polytheism, monotheism, atheism; mythology and mythogeny; symbolism and religious art; sacred

places and objects; rites, ceremonies and mortuary customs; religious teachers, classes, and doctrines; theocracies; analyses of special religions; philosophy and natural history of religions.

4. **Linguistics:**—Gesture and sign language; spoken language, parts of speech, logic of grammar, origin, growth, and classification of languages, relation to ethnography; written language, pictographic, symbolic, ideographic, and phonetic writing, evolution of alphabets, phonetic systems; forms of expression, poetic (metrical, rhythmical), dramatic, prosaic.

5. **Folk-lore:**—Traditional customs and narratives, folk-sayings, superstitious beliefs and practices.

## III. ETHNOGRAPHY.

1. **General Ethnography:**—Origin, characteristics, and subdivisions of races and peoples. The "geographical provinces" or "areas of characterization." Anthropo-geography. Lines of migrations and national intercourse.

2. **Special Ethnography:**—The Eurafrican or White race (North Mediterranean and South Mediterranean branches), the Austafrican or Black race, the Asian race (Sinitic and Sibiric branches), the American race, Insular and Littoral peoples (Nigritic, Malayic, and Australic stocks).

## IV. ARCHÆOLOGY.

1. **General Archæology:**—Geology of the epoch of man. Glacial phenomena. Diluvial and alluvial deposits. Physical geography of the quaternary. Prehistoric botany and zoölogy. Prehistoric Ages.—The Age of Stone (palæolithic period, neolithic period); the Age of Bronze; the Age of Iron; prehistoric commerce; palethnology; proto-historic epoch.

2. **Special Archæology:**—Egyptian, Assyrian, Phenician, Classical, Medieval and American Archæology.

The urgent need of a uniform classification and nomenclature for the various sciences connected with the study of man must be apparent to all who are familiar with the current literature of anthropology.

The plan proposed above is based upon the works and suggestions of well-known English, French, German, Italian and American writers. The proposer claims no other credit than that of selection. He offers no neologisms. The leading terms, those printed in black type and capitals, are substantially the same in all the languages named; they are already domesticated in the anthropological writings of every country; and all that is needed is a general agreement as to their connotation.

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TUSAYAN LEGENDS OF THE SNAKE AND FLUTE PEOPLE. By MATILDA COXE STEVENSON, Bureau of Ethnology, Washington, D. C.

MY present subject was suggested by the very interesting article of Doctor Fewkes on the flute ceremonial at Shu-pow-o-la-vi one of the Tusayan pueblos. (A Journal of American Ethnology and Archæology).

I was never so fortunate as to be at Tusayan at the time of the snake ceremonial, a celebration which equals the most incredible representations of the snake charmers of the Orient. The matter published in 1885 on the Moqui snake dance was gathered from Messrs. Keam and Hubbell of that country, and several members of the snake society. Having thus culled some of the fruit, I sought the tree which bore the fruit I was so fortunate as to discover the tree in the two legends given below as nearly as possible in the words of the theurgists of the snake and flute societies.

### THE SNAKE DRAMA.

The weird and curious snake drama will be described only so far as to make clear the character of the organization whose duty it is to furnish actors for this remarkable histrionic performance.

The following account, which is presented as an introduction to the legends was given hurriedly at odd times by a member of the snake order now residing in Zuñi. My familiarity with the secret cult-societies of the Pueblo Indians enables me to see that the statement in general is correct, though in detail it may be subject to criticism. My rule is never to regard such material of real value until it has been verified from the tongue of more than one intelligent Indian, no religious or social secret being held by any one man.

The snake society is a cult organization admitting both males and females, regardless of clans; the officers of the society, however, must be of certain clans, including those of the snake and the antelope, as will appear further on in the legends. The society has three divisions or orders: (1) the O'wi-yu-to-ti-ni, medicine; (2) Chur-wim-tka, rattlesnake; and Lé-lur-kang-a, a snake of a yellowish color, spotted with black. The following description relates entirely to the rattlesnake division or order.

A woman chosen from the order looks after the cooking of the "root medicine"; she has an assistant whom she instructs with a view to filling her place upon her death. The Chá-a-ka-mûng-wi (maker of medicine water) powders and prepares this root medicine, when the woman takes it in charge and boils it in the kiva, or assembly chamber. This medicine is an emetic, and is drunk morning and evening the first four days of the ceremony, for mental and physical purification. The root held in the mouth while one expectorates over himself to prevent the anger of the snakes is quite different. When one is bitten by a snake this root is chewed by the theurgist, who, after sucking the wound four times, expectorates upon the lesion four times while the root is in his mouth; a wad of raw cotton is then bound upon the wound.

The Tusayan hold the same superstition as the Zuñi, that one suffering from a snake bite must not look upon a woman furnishing nourishment to an infant.

After the morning meal, the first day of the ceremonial, the male members go to the north to gather snakes; on the second morning they go to the west, the third to the south, the fourth to the east; and on the fifth and sixth mornings they look about generally for the zenith and nadir. The snakes are deposited in four vases which stand in line at the western end of the room, and on the northern side.

On the fifth morning a sand painting is made on the floor of the kiva, and fetiches of the cougar and bear, so conspicuous in the snake legend, are deposited by it. The male novitiates sit in line north of the painting. The men of the society sit on the southern side of the kiva and the women on the northern side. The snakes are deposited on the painting, where they are frequently sprinkled with meal. They are kept there by the novitiates who are busy with wands composed of two eagle plumes attached to a slender stick held in the right hand. The Indians declare that the eagle possesses the power of charming the snake by flying about him and gently caressing him with his wings, and these children of nature have adopted the eagle's plan, using the wand.

The male novitiate has the snake placed in his mouth by his chosen father who has first held it in his mouth and danced while an attendant caressed the serpent with the eagle plumes; before the snake is put into the novitiate's mouth the chosen father grasps it with both hands, the span of the tip of the middle finger to the tip of the thumb from the head, and, moving it before the face of the novitiate, prays, while the novitiate inhales, taking in a breath from the snake. After the snake is put into his mouth the novitiate dances while the attendant waves the plumes over the snake. With a female novitiate the snake is only waved before her mouth (the women of the order never handle the snakes); and a similar ceremony is observed with both sexes when entering the Lé-lur-kang-a. Many men and women belong to more than one of these divisions, yet it is only those holding membership in the rattlesnake order who participate in the snake drama. It is the ambition of the men to join the rattlesnake division, not only to prove their skill in handling the snakes, but because the people of this order are considered the greatest jugglers in the Province of Tusayan.

At sunset the snakes are removed from the sand painting and returned to the vases. In the morning a fresh painting is made and the snakes deposited upon it. This is repeated four days in succession.

After the out-of-door ceremony in which each dancer has an attendant whose duty it is to control, with a feather wand, the one or more snakes held in the dancer's mouth, an all-night ceremonial occurs in the kiva, principally for the final initiation of the novitiates, when their power of endurance is taxed to the extreme.

At sunrise the novitiates form in line in the kiva facing eastward, when the head of each is bathed in yucca suds by the wife of the chosen father, and a pair of moccasins, some calico, and four plume offerings are presented to him by the father. These plumes are afterwards offered by the novitiates to the rattlesnake.

I have given but the faintest glimpse of a most elaborate ceremonial of initiation into the snake order. The medicine order is usually the first joined. When one has been cured by the theurgist, either the patient or his parents notify the theurgist of his wish to join the O'wi-yu-to-ti-ni the theurgist becoming the father of the novitiate. When either of the other two orders are joined the novitiate may or may not choose the first father. In every instance the father presents a pair of moccasins and some minor gifts, usually calico, and the washing of the novitiate's head in yucca suds by the wife or daughter of the father at sunrise invariably closes the ceremonial.

Why the snake ceremonial is biennial is a question often asked. It is answered in the legend of the flute people which is embodied in the drama so vividly portrayed by Dr. Fewkes as performed by the members of the flute society. But the legend of the snake people must precede that of the flute people. It is as follows:

### ORIGIN OF THE SNAKE CEREMONIAL.

When our people lived in the cliff in Cañon de Chelly much water fell through the cañon into the San Juan river. The son of the high shaman of the Ho-pi-tu (Tusayan) said to his father, "Father, I have long desired to launch a boat upon these waters and see where the great river flows." The father replied, "My son, I fear you will never return to your people, but if you desire to go I will aid you all that I can. Surely you have a brave heart and I am proud of you." When the mother and sisters were told of the boy's ambition and that the father had consented to his wish they were sorely grieved and wept and begged him to desist from so hazardous an enterprise. Four days were consumed by the father in making plume wands for his son, and the mother and sisters were busy preparing food for the journey. A log of cotton-wood was hollowed out for the boat and a paddle made of the same wood. The only opening in this hollowed log was a small aperture in the stern, which served two purposes; when it became necessary to use the paddle to shove the boat from the shore it was projected through this hole, and water was collected through the same opening to drink, and to make pi-ka-mi (mush) of sprouted wheat. This opening was closed with a small pottery vase, the same vase being used to dip water when required. At the end of four days all was ready, and the youth launched his boat upon the stream and departed amid the tears of his people who feared they would never again see the dauntless boy.

He floated many days, he could not tell how long, for he knew not days from nights as all was darkness in the boat. Finally running against the shore he determined to land. After landing he selected from his many wands one which was very large, made of beautiful white feathers of the eagle and he planted it in the ground and asked his sun father to lead him over the right road, begging him that the wand might direct his steps. He was led by the wand a long distance, and finding no one, he again planted it in the ground and asked the sun father that he might be directed by the wand; and the third and the fourth time the wand was planted and the supplication repeated, until finally he reached the house of the spider woman, the little grandmother. The old woman said, "My child, what brings you here? You are near a very bad people. Come into my house and I will talk with you." It must be remembered that the little old grandmother could not be seen, but she was all the time close to the youth's ear. After entering her house he said to her, "I am not afraid and I would like to go and see the people of whom you speak." The spider woman said, "I must first give you medicine which you will take into your mouth and eject upon the bad people and they will at once become friendly." And he visited these people accompanied by the grandmother who traveled close to his ear. He had to pass four sentinels, equidistant from one another. Each sentinel was a huge serpent who held his head erect and hissed at the youth as he approached, but upon spitting the medicine upon him he became docile and allowed the youth to pass. The road led into a rocky cavern of great beauty and upon entering the first kiva in this cavern he saw many youths and maidens. The youths wore only breech cloths which were white. The maidens were clad in pure white blankets and they wore earrings and necklaces of turkis and kohaqus. The youths were on one side of the kiva and the maidens on the other, and the mûngwi or director was passing between the two, distributing plume wands; he had a bald head, as bare as the rest of the body. When the youth entered the kiva the mûngwi exclaimed, "Who are you that you dare come to my house?" The youth told him where he lived and how, desiring to see the world, he had made him a boat and floated down the great river. "You are surely brave to venture here. Come, I will take you to the house of my brother." And he led him into an adjoining kiva, where many youths and beautiful maidens were dressed like those in the first kiva. The mûngwi of the first kiva told the story of the stranger to the mûngwi of the second kiva who welcomed the youth, telling him he was a noble fellow with a brave heart to come so far to a strange land. The mûngwi of the first kiva was the director of the snake people, and the mûngwi of the second kiva, the director of the antelope people. The director of the antelope people said to the youth, "Do you not wish one of my beautiful maidens for a wife?" The spider woman who all the while traveled close to the youth's ear, whispered, "Wait; wait awhile." And the youth without replying bade farewell to the mûngwi saying in a little while he would return.

Again the youth went to the house of the spider woman, and she said to him, "I will now lead you to the house of the sun; the mother of the sun lives under the great waters." And when they had reached the shore the youth separated the waters with his large wand, making a dry road between the waters, over which he passed to the house of the mother of the sun. This house was very beautiful and here he saw all the plume offerings of his people, those of the good of heart were on one side of the house and those of the bad of heart on the other side. He was welcomed by the mother of the sun who told him in a little while the sun would return. Presently the youth was startled by a great noise caused by the sun returning through the waters to his home. The descent was through a huge reed; putting a foot on either side of the reed he descended head foremost. The spider woman whispered to the youth, "We will go with the sun to his father's house in the east," the mother's house being in the west; and they in company with the sun passed under the earth and visited the father's house in the east, and from the father's house they ascended through the reed that penetrates the eastern waters and passed over the world. On this journey the youth saw all his people in Cañon de Chelly and could read their hearts, and he knew the good of heart from the bad of heart, and he returned with the sun to the mother's house and saw the sun deposit the plumes he had gathered while passing over the world, placing the plumes deposited by the good of heart on the one side and those by the bad of heart on the other.

Returning to the earth the youth again visited the cavern of the snake and antelope peoples. The spider woman continued to remain close to his ear. Upon entering the kiva of the snake people the mûngwi asked him if he did not want one of his beautiful daughters for a wife. He had two daughters. The spider woman whispered to him to take both, so he said to the mungwi, "I wish for both of your daughters as wives;" and the mûngwi answered, "It is well, they are yours." The youth accompanied by the two maidens bade farewell to the snake and antelope peoples and was led by the spider woman to her house. On reaching home she said to the youth, "Here you and the maidens will remain four days. The maidens will be my cooks and I will teach them all that I know." Then she directed the youth to gather young cottonwoods and build a house for the maidens to live in during their stay with her. After the fourth day the youth, in company with the maidens, started for his home. He was accompanied on his journey not only by the spider woman but by the cougar and bear who acted as his warriors or protectors; but they, like the spider woman, could not be seen. The spider woman led the way, and upon reaching the cañon she said to the youth, "You cannot climb down; the road is too steep; prepare a box of cottonwood and you and the maidens get into it and I will let you down with a rope of cotton which I will draw from my own body." And in this way they were safely landed in the cañon of his fathers and he hastened to his home where he was received amid great rejoicing of all the people. The maidens were welcomed by the father of the youth who said to them, "Four days you will remain apart from my son and grind meal and make bread." On the morning of the fifth day the mother and sisters of the youth bathed the two maidens in suds of yucca, after which they for the first time were seen by the Ho-pi-tû.

The eighth day and night after the return of the youth was consumed in smoking and talking with his father. The father talked to the youth and the youth gave his father an account of his journey down the river and the strange people he visited. All day and night they talked, and the father said, "My son, at sunrise you will go and tell all the people of the village that in sixteen days we will have a great feast to the snake and antelope peoples. Tell the men, women and children that in eight days from this time they must run to the north, to the west, to the south and to the east.

The same day that the men and women ran, the two maidens and the youth and his brother entered kivas. The youth accompanied one of the maidens to the kiva dedicated to the antelope people, and the brother accompanied the other maiden to the kiva dedicated to the snake people. These couples remained alone in the kivas three days. The maidens taught their companions the antelope and snake songs. The third night the cougar and the bear descended into the antelope kiva. The next morning the cougar invited the antelope people to come to the ceremonial and the bear invited the snake people. The snake people came in showers. There were four delicate showers, each shower bringing the people. These showers were, however, invisible to the Ho-pi-tû. Certain of the Ho-pi-tû were also invited. The youth did not invite all of his people, only those of the good of heart; he having in his travels with the sun, been able to know the good of heart from the bad of heart. The morning after their arrival the antelope and snake peoples began, at sunrise, to sing; and they sang for three days. The seventh morning the brother in the snake kiva accompanied by the Ho-pi-tû in that kiva spent the day with the people in the antelope kiva. The same day a man from the antelope kiva and one from the snake kiva, both of the corn clan, were selected by the youth and his brother to gather green cornstalks which were held in the mouths of the Ho-pi-tû when they danced on the eighth morning in the plaza. Upon the return of the youth and his people to the snake kiva in the evening they were horrified to find that the snake people had been transformed into snakes. The spider woman whispered in the ear of the youth, "Do not be afraid, I will give you medicine which will make the snakes friendly; to you alone I will intrust the secret of this medicine, and to the maiden the care of cooking it. You will take it into your mouth and spit it upon the snakes. I will also give you a medicine of which you will drink much and should you be bitten by an angry snake you will not suffer because your heart will be pure."[1]

At midnight, the youth and his brother directed the Ho-pi-tû in the two kivas to go out and plant plume offerings, saying. "You of the antelope kiva and you of the snake kiva must plant your plumes apart, but your prayers said over the plumes will meet as in one straight tongue." The following morning the bear went from the antelope kiva to the snake kiva and holding each snake the length of the tip of the middle finger to the tip of the thumb from the head bathed it in yucca suds and rubbed it with sacred meal and deposited it in a large vase. The same morning the youth of the antelope kiva selected two young men, good of heart, and directed them to cut young cottonwoods and build a house for the snakes, instructing them how it should be built. Upon its completion the snakes were deposited in the house; the remainder of the day was consumed in out door dancing, the cornstalks being held in the mouth. After the planting of the plumes by the Ho-pi-tû neither food nor drink was taken until after the dance. At the close of the dance the medicine of the spider

[1]This has reference to the decoction taken in the morning and evening which according to the Ho-pi-tu belief so thoroughly purifies the man mentally and physically that he is, for the time being, impervious to evil.

woman was freely drunk which induced vomiting, after which a feast was indulged in. When the dancing ceased, the spider woman whispered to the brother, "Catch the maiden who was transformed into a snake (the sister who was in the antelope kiva escaped this transformation), and carry her back to the kiva; but the other snakes must be deposited to the north, the west, the south, and the east so that they may return to their homes." This was the natal festival of the snake society of the Ho-pi-tû. The brother had no sooner placed the snake in the kiva than it was again metamorphosed into the beautiful maiden. The youth with the two maidens returned to his father's house and they became his wives and he was enamored of them. In four days the maidens had every appearance of approaching parturition. On the eighth day after their marriage the maidens deposited many eggs which they covered with mounds of sand, and in four days tiny snakes were hatched. All the children of the village were delighted with the little snakes and played with them; but in four days the snakes grew to be very large and became angry and bit the children, and all the children bitten died. Every four days new snakes were hatched and these grew like the others to be large and angry in four days. Finally the youth's father said to him, "Your children are no good. I am in despair for all of our little ones have been destroyed by your children. All of my people's hearts are sad. Where shall I go with my people to avoid your destroying children?" And he called two chapparal cocks to him and said, "Go hunt a good road where we will have water. I wish to leave these people and seek another country." The birds traveled apart and on their return they told their story and a road was selected. The high shaman traveled only as far as the birds had gone, they having taken different routes and meeting at a certain point. Again the birds were dispatched to find a good road, and in this way the shaman traveled until he reached the present country of the Tusayan. He camped at the base of the mesa upon which stands the present village of Wálpi. When some distance from this point the shaman, discovering a man at the foot of the mesa, said to his people, "Get your arrows ready; I will go ahead and see who this man is;" and he advanced to meet the stranger who was approaching. When a ditch only separated them the stranger, who was a giant, exclaimed, "You are a brave man to come here; I thought you would be afraid; we will have a smoke;" and he drew a huge pipe from his belt. The shaman smoked the pipe, and the giant said, "You are surely a good man; you have smoked the pipeful of tobacco; I will give you more;" and the shaman smoked four pipes of tobacco. Then the giant said, "I am much pleased that you are not afraid. I will give you land for your people, and you will make this your home."

This legend furnishes the plot for the snake drama which occurs biennially at Tusayan.

### ORIGIN OF THE FLUTE CEREMONIAL.

Lé-lang-ûh was the original director of the flute people. The music of his flute drives away the winter, and brings the summer rains. He had many necklaces of turkis and kohaqua, and he wore earrings of turkis, and parrot plumes upon his head. He was the director of many people and his insignia of office was the Pá-a-ya, a crook, symbolic of longevity, to which were attached four rattles ornamented with the fluffy breast feathers of the eagle. The rattles were used by him when he sang for rain, to water the lands of the snake people upon his advent into this world from the lower world.

Lélangûh erected an elaborate pó-ñai, a portable altar constructed of wood slats, and in front of it he placed his mother tí-po-ni (a fetich of an ear of corn, with eagle and parrot plumes arranged at the top in pyramidal form; the corn is closely wrapped with native cotton cord, at the top of the wrapping bits of abalone shell, turkis and other beads are suspended). The songs for rain were sung to the accompaniment of the flute and the rattle. The songs were sung to the rain people of the north, of the west, the south, the east, the zenith and the nadir. The six songs brought the rain, and Lélangûh blew his whistle into the water which fell upon the earth, making it bubble, at the same time praying for more rain; and the earth was well watered. After long prayers and songs to the póñai that it would lead them over the right road, Lélangûh was informed of the path he was to follow. The póñai was taken apart and carefully packed and the típoni placed in a box which was wrapped in a white cotton blanket and carried over the shoulders of Lélangûh. Two of his shamans carried the póñai on their backs. Lélangûh directed by the póñai and mother típoni traveled from the northwest and crossing the Colorado river camped on the banks of the Rio San Juan near its junction with the Rio de Chelly. The flute people lived at their camp on the Rio San Juan four years (years referring to periods of time). Lélangûh thought much of where he would go with his people; he finally called the mountain sheep and the antelope and told them he wished them to hunt for a good land and to return and inform him when they found such. The mountain sheep traveled on the west side and the antelope on the east side of the Colorado river, and after running one day they both returned to the camp. Lélangûh then erected the póñai and placed the típoni before it and prayers were sung to the music of the flute and the rattle. The prayers brought the rain which watered the earth. The póñai was removed and the típoni replaced in the box and wrapped with a cotton blanket, and Lélangûh followed the course indicated by the póñai and the típoni. He with his people advanced to the Colorado river. Upon reaching its banks they traveled one day down the river and made camp and afterward built houses. They lived at this village one year or time period; he then moved on and built another village where they lived one year; here there was much good water and the people drank and quenched their thirst. Again the póñai was erected and the típoni placed before it and the antelope and mountain sheep were sent to hunt a place where a village might be built. In the evening they returned declaring they had found a good country. In four days the flute people started on their journey and after four days' travel reached the country selected by the antelope and mountain sheep. The pónai was again placed with the típoni in front of it and songs were sung to the music of the flute and the rattle that they might be informed what route to take to find a good country. The póñai fell in the direction the people were to go. Instead of proceeding they were directed back to the village last vacated. They remained at this village one year after their return, when the póñai was again erected and the típoni placed in front of it that they might be directed to a good country. They followed the course indicated by the póñai and the típoni and reached a point some six miles from the present pueblo of Wal-pi. Here they built the village Quash-ta-pa. In the distance a bright light was visible, it burned continually in the day and in the night. Lélangûh said "I would like to know what people live there," pointing to the light, "perhaps they are good, perhaps bad." I will send the antelope and the mountain sheep to learn what they can of these people. Upon the near approach of the antelope and sheep to the village they discovered the people were red all over and when still nearer found them to be snake people. The antelope and mountain sheep had drawn near to a spring when the snake people attempted to seize them. They were too tired to run fast and were captured. The director of the snake people inquired "Who are you? Where did you come from? Where are you going?" The antelope and sheep replied "our camp is not far off, and seeing a light burning here we came to learn what people live here." The captives were then released and allowed to go to their village. Upon their return they smoked the pipe with their director and informed him of their adventure. They told Lélangûh how they had discovered the people passing in and out among the rocks near a spring at the base of a mesa, and how they feared they would be killed by them when they were captured, and after they were caught how the strange people inquired who they were and whence they came. Lélangûh said "I will go and see these people and tell them we are poor." But he wished first to have the words of the póñai and típoni, and in four days he erected the póñai and placed the típoni and sang to the music of the flute and the rattle. He first sang for rain, which came, and in conjunction with the póñai the rain told him it would be well for him to go and see the strange people. After packing the típoni in the box and wrapping the box with a white cotton blanket and separating the póñai so it could be carried by the two shamans, he placed wands on the road they were to take, and he, followed by his people, proceeded to the home of the snake people. He carried much meal and sprinkled it making a road all the way for his people to pass over. Lélangûh thought much of the people he was to meet. He said to himself, "Perhaps they are bad." At sundown they were not far the snake people whom he discovered to be advancing towards him. The director of the snakes was in front followed by his people many abreast. Upon reaching the flute people the director of the snake people cut the road of meal saying "We do not wish you in our country, we do not know you, and you may be bad people." Lélangûh replied, "No, we are not bad people, but we are very poor and have traveled far, we wish to live upon your land." Again the director of the snake people objected. And thus they argued until they had had four talks. In the last talk Lélangûh told the director of the snake people that he knew the secret of the rains and could water his land for him. "Well," said the director," if you can command the rain people your heart must be good, and we will be glad to have you with us if you know the secret of the rains. If you know this secret then you and your people must be first and I and my people second; you will be to us father and mother, you will always be our great father." The flute people camped with the snake people four days, then the director of the snake people being impatient for rain said to Lélangûh, "If you indeed know this secret, hasten the rain that our land may be watered." "Wait," said Lélangûh, "in eight days I will return to your village and we will go into the kiva." The director of the snake people thought, "I guess this man has lied to me." Lélangûh returned with his people to Quash-ta-pa, but in eight days he, accompanied by his people, again visited the snake people, he with all of his men, two young virgins, and a youth not having reached maturity went into the kiva of the snake people. The director was the only one of his people to accompany Lélangûh into the kiva. The two virgins wore white blankets. The lower portion of the face was painted black; a white line across the mouth and extending from ear to ear bordered the black; their feet and hands were colored black, their arms and legs on the outer sides were zigzagged in black,—this decoration being symbolic of rain and lightning. Each wore a white fluffy eagle plume attached to the forelock. The youth wore a white breech cloth and an eagle plume in his hair, his person being decorated similar to the virgins. They wore elaborate necklaces of turkis and kohaqua. The director of the snake people first placed his tiponi before the póñai, which Lélangûh had erected, then Lélangûh deposited his tiponi. They remained in the kiva four days, during which time they ate no animal food nor salt and practised continency. They subsisted on pi-ki, a wafer-like bread, and pi-ka-mi.

On the fifth morning all the flute people returned to Quashtapa excepting the youth and the two virgins; these remained in the kiva. They traveled by the music of the flute and the rattle and were led by five large beautiful feather wands. After reaching their village they had a feast and ate much meat and salt, and after the feast they sang all night. At midnight they had sung four songs when the rain slowly approached. It came not in showers from the heavens, but walked over the earth. As yet, before it was day, the waters were invisible to all but Lélangûh. Before daylight the women attired themselves in white blankets and the men in white breech cloths having painted their bodies and limbs white, and ascended the mesa before their village. Lélangûh carried the five large wands and was accompanied by the twin war heroes. (These little fellows figure extensively in the mythology of all the Pueblos.) Again songs for rain were sung and the wands planted. Then Lélangûh accompanied by his people advanced to the land of the snake people. All his men had sunflowers on their heads and they carried corn and many seeds of melons, beans and peppers. As they neared the village the rain began falling around the land of the snake people but not upon it. They were met by the snake director and his people; and the two virgins and the youth who had remained alone in the kiva of the snake people abstaining from animal food and salt since the day they first entered with Lélangûh, soon appeared, accompanied by the two war heroes who upon entering the kiva heard the prayers of the youth and the maidens and then led them to where the people were congregated, but they did not join in the dance. After the fourth song the rain began falling upon the land of the snake people and in a little while the land was well watered and the snake people wept for joy. Lélangûh gave to the snake director all the cereals his people had brought and the snake director was greatly pleased and said: "You are indeed my father, you have brought us rain, you know the secrets of the rains, you are therefore before me." The rain was so heavy that in places it washed the earth into globules and Lélangûh gave to each of the virgins four of these balls and to the youth four eagle plumes. The virgins and the youth preceded the others to the kiva of the snake people; as they advanced a line of meal and four rain symbols equidistant were outlined in meal. The youth planted an eagle plume at the center arch of each design and the maidens placed the mud balls in the arches either side of the line.

After all were seated Lélangûh placed some mountain sheep's chips upon the floor and on these a beautifully decorated pottery bowl. He then placed a yellow ear of corn to the north of the bowl, a blue ear to the west, a red to the south, and a white to the east; a black for the zenith was placed by the side of the yellow ear and the all-color for the nadir by the side of the red ear. He then held a small vase of water which he brought from Quashtapa, extending it to the north, he sang for rain and sprinkled the yellow ear of corn; then extending to the west he sang for rain and sprinkled the blue ear, and so the songs to the south and the east and the zenith and the nadir were sung, and the ears of corn sprinkled; he then emptied the water into the bowl. Six pebble fetiches for the cardinal points were dropped into the bowl with invocations to the cougar of the north, the bear of the west and badger of the south, the white wolf of the east, the eagle of the heavens and the shrew of the earth to intercede for rain. Lélangûh then blew his whistle in the water, producing bubbles, and much rain fell, and again the snake people rejoiced. Lélangûh, taking the six fetiches from the water, blew smoke over each one and prayed that his people might be preserved from evil and have good health. The flute people sang all the time, but the snake director did not sing for he did not know the songs for rain. Lélangûh directed his people to make plume offerings to be deposited to the north, the west, the south, the east, the zenith and the nadir. The offerings were planted by one man for the snake and flute people. The plumes carried prayers for all things good. Upon leaving the kiva the flute people saw their women sitting on hills outside of the village watching for them. The women wore white blankets and the children had white plume from the breast of the eagle fastened to the forelock. The men still wore the sunflowers upon their heads. In a little while the land was abundant with melons, beans and peppers and other vegetation, though nothing had been planted. At sunrise the following morning all the men and boys of the flute people painted their bodies white. The white plume from the breast of the eagle and parrot plumes were attached to the scalp lock of each boy's head; the men wore sunflowers on their heads; all had many fine necklaces of turkis and kohoqua beads. Lélangûh played and sang and the women and youths ran about for all were now contented. At midday Lélangûh with his men, and the snake director, went into the kiva, and Lélangûh repeated the making of the medicine water and again much rain fell. At the close of the ceremonies Lélangûh said to the director of the snake people, "You have seen my people dance; you have heard my songs and prayers, you know that I speak with one tongue and have a good heart." "Yes," replied the snake director, "you know much, we must live together; you have made my land rich with food, you are great. You must be at the head and I will follow. The land will be yours for one year during which time all my people will be after you, then I will be at the head, and the land will be mine, and thus we will rule over the land. You have taught me the secrets of the rains and the land will be yours as it is now mine."

The flute ceremonial is the dramatization of the migrations of the flute people, their encounter with the snake people, and the grand finale when the director of the flute people brings the rains, and in return the director of the snake people declares that he shall be master over the land every alternate year. With a knowledge of the language, infinite details could be introduced into the legends which exhibit such striking analogy to the ceremonials of the snake and flute societies.

While the snake and flute people are allied, the snake drama bears no relation to the flute drama except in so far as they are both rain ceremonials; but in the flute drama, both the flute people and the snake people appear. Without positive knowledge, I should say that those personating the snake people in the drama of the flute society are members of that body.

Ethnologic investigations are extremely fascinating; but exultation and enthusiasm often engender mistakes, and mythologic questions are frequently shrouded in mystery. In some respects they are like the acts of the prestidigitator which at first appear to be impossible of solution, yet at last when the secret of the process is revealed, its very simplicity dulls the glory of discovery. Such is often the experience of the ethnologist in studying mythologic and sociologic phenomena. Each particular question, without careful comparison with others, confronts us with strange confusion, but upon further research a solution may often be found.

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PRIMITIVE NUMBER SYSTEMS. By Prof. LEVI L. CONANT, Polytechnic Institute, Worcester, Mass.

[ABSTRACT.]

THE number sense is never wholly lacking, no matter how limited may be the mental development of a tribe. Even the higher orders of the brute creation seem able to distinguish between *one* and *two*. Investigation must then begin with modes of expression of number, and not, as many philosophers have argued, with number itself. Different primitive methods of notation. Counting with the assistance of the fingers the universal starting point for number systems. It is the method of childhood, and is common among eastern nations to-day. Extent of various primitive number systems. Examples of tribes unable to count beyond 2; beyond 3; beyond 4; beyond 5; beyond 10. Formulation of a general law for the method of counting in vogue among savage tribes. Only the vaguest notions possessed by savages of the numbers they use. Even though they count as high as 100 or 1000, they are often unable to distinguish between very small numbers. The systems of the modern civilized world, now unlimited, were once as limited as those of the savage races now in existence. The testimony of language decisive on this point. Until comparatively recently it has been supposed that all the number systems of the world were decimal. The decimal a natural scale, because of the ten fingers. But the quinary and vigesimal are equally natural. The best of all possible bases is 12. Reasons therefor. Reckoning by 12's very common in business transactions, but no people has ever used 12 as its exclusive number base. Examples of tribes that have used as their base two, three, or four. Brief mention of a similar use of six, seven, eight, nine, eleven and sixty. Consideration at length of the quinary system. Examples of its use. When extended, the quinary always passes into the decimal or the vigesimal system. Consideration of the vigesimal system. Examples of its use. Traces of its former use. Consideration of the decimal system. Its widely extended use. It seems destined to supplant all other systems, as it already has done in very many cases.

[This paper will be printed in greatly expanded form as the first chapter of a book.]

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THE PEABODY MUSEUM HONDURAS EXPEDITION. By Prof. F. W. PUTNAM, Curator Peabody Museum, Harvard University, Cambridge, Mass.

[ABSTRACT.]

A BRIEF account of the Expedition to Honduras during the past winter, with a statement of the plans of the Museum for future work in that country.

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EXPLORATIONS ON THE MAIN STRUCTURE OF COPAN, HONDURAS. By MARSHALL H. SAVILLE, Asst. Peabody Museum, Harvard University, Cambridge, Mass.

[ABSTRACT.]

THE Main Structure of Copan is one of the most marvelous and instructive in the New World. It was not understood by Stephens, who

could see no evidence of any buildings in connection with it, and the forest still covered it when the Peabody Museum Honduras Expedition reached Copan in December last.

This great ruin is of irregular shape, the length along the river front being about 780 feet while the western side is about 560 feet. The height at the highest point above the river is about 120 feet.

Among the numerous mounds of this Structure is mound 21 in the extreme northeastern part, overhanging the river. It is on the upper level, above the western and eastern courts. The steps on the northern side of the Main Structure lead up directly to this level, which runs along the top of the northern part of the Structure, and southerly to pyramid 16, thus separating the two courts.

This mound was much destroyed and the space between mounds 20 and 21 was filled with debris from both mounds, to a depth of ten feet. At the southern side of the mound could be traced a flight of steps nearly destroyed, leading up to the top, which is fifty-one feet above the eastern court. The debris filled the space between mounds 21 and 22, and the general appearance of the mounds was that of a mass of stones and earth upon which large forest trees were growing.

After clearing away the forest from the whole eastern part of the Main Structure, excavations were begun at the southern end of the debris between mounds 21 and 22. Working north to clear the supposed passage between the two mounds, a flight of steps, four in number were discovered, which on being cleared were found to lead to a platform five feet above. At the base of the lower step, on each side, are the remains of a wall which faced the terrace, but the debris falling from the corners of the two mounds has left only the lower course of stones in place. The platform or terrace is 27 ft. feet long, extends between the lower terraces of both mounds, and is cemented. Working north from the top of these steps, about eight feet, the front wall of a building was found, running from east to west with a doorway in the center 6 ft. 10 in. wide. This wall had fallen outward, and was nearly destroyed. It is three feet in thickness and is built on the floor of the room and set in from the southern edge about four inches, a custom observed in the construction of other buildings in Copan. The floor of the room is one foot and a half above the platform and on the steps are several discs cut in the stone. This chamber was found to be 26 ft. long and 7 ft. wide. In the eastern end, the second terrace of mound 21 makes a platform 2 ft. 9 in. high and 4 wide, covered with cement 2½ in. thick. The two upper courses of stone project about three inches. The roof stones still in place in the northeast corner show the room to have been 8 ft. 2 in. high to beginning of roof. The end walls also have roof stones. These roofs were made by the overlapping of the stones on each side until they approached within about two feet, then the two walls were covered by a capstone. In the western wall is a niche nearly four feet from the floor, 1 ft. 9 in. long, 1 ft. 10 in. high, the bottom cemented, and having a flat roof above. This wall has been thrown inward by the fall of the eastern wall of mound 22.

In the center of the northern wall of this room, which is 3 ft. 6 in. in thickness, is a doorway 8 ft. 8 in. wide, leading to a rear chamber. The floor of chamber 2 is more than two feet above chamber 1, the cement being from four to six inches deep. The step is of three courses of stone, the upper course projecting about three inches and has an hieroglyphic inscription cut upon its face consisting of sixteen glyphs. The first glyph resembles the heading which is usually found at the beginning of inscriptions on the stelæ of Copan and Quirigua and on the inscriptions of Palenque. The divisions of this inscription are unique, the character being two discs, joined together near the lower part by a loop. They are placed, one after the first three glyphs, the next in the middle and the third before the last three glyphs. Below the central part of this inscription, on the lower courses of stone, is a large square cut in the stone. On each side near the top is a small square at right angles with it. About one foot away on each side a circular piece has been cut out. The characters resemble those cut in the stones of the roof of the "House of the Dwarfs" in Uxmal, Yucatan.

The room into which this step leads is 25 ft. 9 in. long and 6½ ft. wide. The terrace of mound 21, as seen in chamber 1, rises but eleven inches above the floor. The roof stones begin about six feet above the floor, and in the western wall was formerly a niche, now destroyed. The back wall of the room and building is five feet in thickness and has fallen outward.

The cement on the floor of chamber 1 is rather broken, but that of chamber 2 is cracked and raised. This line of rupture runs from east to west, and continues through the western wall of the room, and the eastern wall of mound 22.

There is another long crack in the Main Structure running from north to south parallel with the river front. The walls in nearly all the buildings explored in Copan have fallen outward presenting a different appearance from those of the ruined edifices in Yucatan. While the buildings in Yucatan were probably destroyed by vegetation aided perhaps by the hand of man, in Copan we have evidence of a stronger force, probably an earthquake, producing the long cracks seen in the Main Structure, breaking off several idols just above the base, and wrenching others from their foundations.

In the outer back wall is a carved stone probably taken from some destroyed building, and used in the construction of this edifice. The terraces of the Main Structure lead up to this wall, but are now filled with debris. The northeast corner of this building was formerly ornamented, but with this exception no sculptures were found in a position indicating that they formed part of the wall. The sculptures found in excavating were in all probability from the buildings on mounds 21 and 22.

Continuing our work eastward we found that mound 21 was composed of five terraces rising one above the other, forming a rectangular structure. These terraces on the northern side are destroyed and on the eastern side have fallen into the river, but the western and southern sides are in a good state of preservation. They average a little over four feet high and are about three feet wide. The two upper courses of stone project in all with the exception of the lower terrace, in which the three upper courses form a projecting coping. The corners seem to have been literally swept down by the mass of debris falling from above.

Built against the southern side of the mound is a steep flight of steps, made of small stones, which once led up to a low platform one foot in height, on the upper terrace. Above the fourth terrace these steps were of larger stones, but they are now destroyed. They average about one foot high, one foot broad, and nineteen are now in place. The base of the steps is about thirteen feet from the base of the lower terrace, and on each side of them are small terraces or platforms, formerly eight in number, rising to the top of the mound. The roots of trees have done much to destroy the upper part of these massive steps, but the lower part are in an excellent state of preservation, and it seems very probable that the building which once stood above, fell before any vegetation grew upon the structure.

The building, which once crowned these terraces, is now almost completely demolished, simply two parallel walls remaining, running north and south, about 6 ft. high and 7 ft. 9 in. apart. Between these walls about six feet north of the front of the building, a flight of steps, of which only five remain, led up to some platform or room, which is now totally demolished. From the amount of masonry which had fallen it seems probable that this edifice was two stories in height, and perhaps was a tower elaborately ornamented.

About ten feet east of the flight of steps is a terrace between the lower terraces of mounds 20 and 21. This is about four feet high, with four steps leading to the platform above. Three feet east is the front wall of a building with a doorway in the center opposite the steps. This building has fallen into the river and only about two feet of the room remains along the river front. The chamber extended from north to south, and had a raised platform at each end. Through this terrace on the level of the floor at the base of the steps, are two small passages about ten inches in height and the same in width. They are located one on each side of the steps and the eastern ends appear on the river front a little lower than the floor of this court, and a little larger than at the western ends. They were probably sewers for draining the space between the two mounds.

Between this terrace and the steps of mound 21 is a small chamber built in front of the first terrace of the mound. The eastern wall of the room is built in front of the northern canal and closes it up. The top of the roof of this chamber is only four feet high and is cemented over. The floor is on the level of the court, and there are two doorways two feet high and about two feet wide, over which are stone lintels. This chamber has the same style of roof as the Yucatan buildings, and extends from east to west. The walls are but two feet high to where the roof begins, and from floor to capstone is three feet three inches. It is 3 ft. 8 in. wide at the floor, 1 ft. 4 in. wide at the roof, and is 6 ft. long.

Over the roof of this chamber and the first terrace, and in front of the second terrace, another small chamber was built. Only the first two courses of the front wall, and portions of the end walls are now standing, the weight of the debris falling from the building above, having completely destroyed the roof, the stones of which were found on the floor. This room was about 14½ ft. long and 4 ft. wide, had three doorways, and in the end walls about two feet from the floor were niches one foot wide and deep. In the outside of the front walls, on each side of the doorways, are small holes like those found in several buildings in Copan and quite common in Yucatan. These are supposed to have been for passing ropes through for curtains or doors. The roof of this chamber could not have been higher than that of the chamber below. The use of these small rooms is a mystery.

In the rooms explored in our excavations nothing was found except the rubbish from the fallen walls. At the base of the steps leading to the top of mound were found seven obsidian discs, from three to three and a half inches in diameter and about one-fourth of an inch thick. One of these has considerable cement on one side and it may have been set into the façade of the building. Three stucco faces and other fragments of the same material were found at the base of the steps showing that the use of stucco, in the ornamentation of buildings, was not unknown in Copan.

At the northern end of the steps, near the first terrace was a large ash-bed on the cement floor, in which were a quantity of potsherds of a rough character, probably of cooking utensils, and several fragments of a human skull. Obsidian flake knives, and other implements, were found in the general digging of this mound. Many fine pieces of sculpture were found at the southeast corner of mound 22 and all along the front of mound 21. Faces, busts, conventional pieces, and many representing featherwork were found in the space between mounds 20 and 21. Many of these show that they were covered with cement and the steps and walls were likewise covered in the same manner. Traces of painting on the cement were not observed.

No lintels were found in the debris of the doorways, and as these are too wide to have had lintels of stone, judging from the size of the stones found, wood must have been used. In Yucatan wooden lintels in a perfect state of preservation are still to be seen, fallen or in place in the buildings, but in all of our excavations in Copan we did not find a trace of lintels of any kind, except the two small ones mentioned above.

In Yucatan the sapote was used for lintels and it is found there abundantly at the present time. Mahogany and cedar, which are as durable as sapote, are to be found near Copan; the climate is fully as favorable for the preservation of wood as in Yucatan, and the vegetation not quite as dense.

It seems highly probable that many centuries have elapsed since the destruction of the buildings during which period the wood has entirely disappeared.

## VANDALISM AMONG THE ANTIQUITIES OF YUCATAN AND CENTRAL AMERICA.

By M. H. SAVILLE, Assistant in Peabody Museum, Harvard University, Cambridge, Mass.

[ABSTRACT.]

THE ancient buildings and sculptures of Yucatan and Central America have within a few years been much damaged and disfigured by the indifference of the natives of those countries, and by the vanity of travellers, some of them unfortunately American, who paint their names in large characters on the sides of the buildings and carve them on the sculptures.

Briefly, I will enumerate a few instances that have come under my personal observation.

The magnificent "House of the Governor" in Uxmal, probably the grandest building now standing in Yucatan, is almost covered with names on the front and on the cemented walls inside. These names are painted in black, blue and red, and the letters are in some cases twelve inches high, and here are to be seen the names of men who are widely known in the scientific world. The "House of the Dwarfs" in the same city has suffered in a like manner. Many of the sculptures which have fallen from the buildings in Uxmal have been wilfully broken, and I noticed particularly that two of the beautifully carved turtles, from the "House of the Turtles," had been broken apparently by a machete.

The large face figured by Stephens in "Incidents of Travel in Yucatan," Vol. 2, page 434, is in a mound in the back yard of a shop in Izamal. This has been almost destroyed. The whole of the face between the eyes and the lower part of the chin is gone, and I was told that the stones thus obtained were used in repairing a fence. On the other side of this mound is the bas-relief in stucco discovered by Charney, and this is slowly crumbling away. The steps leading up to the top of the Great Pyramid are being thrown down; and many mounds in Yucatan are being destroyed at the present time, to furnish building material. In fact, if a bee's nest should be found in one of the old buildings, the Indians would tear down part of the structure to get at the honey.

In Copan, when the Peabody Museum Honduras Expedition compared the condition of the "Idols" to-day with the photographs taken by Mr. A. P. Maudslay seven years ago, it was found that, during that time, some of the very finest sculptures had been disfigured by blows from machetes and other instruments. The Stela given as a frontispiece in Stephens' "Incidents of Travel in Central America" Vol. I, has been much marred by some one who has broken off several ornaments, and a beautiful medallion face from the northern side. One of the faces and several noses have been broken off from the sitting figures on the altar, figured in Stephens in the same Vol. opposite page 142. On some of the idols and altars names have been carved, notably on the back of the Stela figured opposite page 158 in Stephens, and a large fragment has been broken from the same Stela. While excavating in one of the chambers of the main structure we uncovered a beautiful hieroglyphic step, but before we had time to secure a photograph of it, some visitor improved the opportunity while no one was about, to break off one of the glyphs.

In Quirigua a small statue, discovered by Maudslay and removed by him to a small house near the rancho of Quirigua, had the head and one of the arms broken from it during the interval between two visits. This statue was of the highest importance, as it very much resembled the celebrated "Chaac-mol" now in the Mexican Museum, but discovered by Le Plongeon at Chichen-Itza. One of the Stelæ at Quirigua has had a name carved on it quite recently; but the sculptures of this place are in a much better state of preservation than those of Copan owing to their being at some distance from the road, and being covered with a dense tropical growth; while those of Copan are within a mile of the village, and there was formerly a road over the Plaza Grande and among the idols. The burning of the bush, to clear the land for milphas, has also injured many of the sculptures owing to the cracking of the stones by the heat.

While in Nicaragua I learned that the sculptures on the Island of Zapatero in Lake Nicaragua have within a few years been much broken and disfigured. These were described by Squier in "Nicaragua, Its People, Scenery, Monuments, etc.," Vol. 2.

As the governments of Mexico and the Central American Republics are making little or no effort to preserve or care for the antiquities within their boundaries, it remains for the United States to do something to preserve these vanishing memorials of the past. The initiative has been taken by the Peabody Museum, Cambridge, which has been granted, for ten years, the care of the antiquities of Honduras. A wall is now being built to enclose the principal remains in Copan, and a keeper has been placed in charge with strict orders to allow nothing to be destroyed or carried away. Thus a strong effort is being made by the Peabody Museum to protect the wonderful carvings in stone of the ancient city of Copan.

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SACRED PIPESTONE QUARRIES OF MINNESOTA AND ANCIENT COPPER MINES OF LAKE SUPERIOR. By W. H. HOLMES, Bureau of Ethnology, Washington, D. C.

[ABSTRACT.]

*The Red Pipestone Quarry* from which material was obtained by the aborigines for the manufacture of ceremonial pipes is situated in southwestern Minnesota near the town of Pipestone. It consists mainly of a single line of pits and trenches nearly a mile in length extending across a wide shallow valley scooped out of the prairie by glacial ice. This valley is drained by Pipestone creek which descends from the east over an escarpment of reddish quartzite and passes to the westward across the valley through a chain of small lakes, finding its way finally into the Big Sioux river, in South Dakota. The stratum of pipestone is about twelve inches thick, hardly two inches of this being of a quality well suited for carving. The material is a fine grained indurated clay of varying and variegated hues of red. It lies between beds of massive quartzite dipping gently to the east and is obtained at great expense of time and labor. The first discovery of the material was no doubt made in the banks of the creek where the annual floods uncover the outcropping edges of the rocks. From the creek the layer of pipestone was followed to the north and south across the prairie until it disappeared beneath the rising ground inclosing the valley. The ancient pits formed an almost continuous chain upwards of three-fourths of a mile in length. They were originally not above six or eight feet deep in any place and are now marked by wide shallow depressions in the surface of the prairie along the sides of which are low ridges of the excavated earth and stones. In these pits a number of broken stone sledges and hand hammers were found and the prairie is strewn with fragments of the red pipestone. There can be little doubt that the work was begun in pre-Columbian times and it appears to have continued without serious interruption down to the present. The more recent work has been confined to limited portions of the outcrop, the ancient pits being in such places partially or wholly obliterated by the more vigorous and effective operations of men employing the tools of the whites. The quarries are visited each year by about thirty families of Sioux Indians who travel some 200 miles from their reservation, spending a month or six weeks in camp about the quarries.

The stone is removed in small pieces and distributed among the families who proceed to make it up into pipes and trinkets of various kinds, or sell it to the whites who, with lathes and other mechanical contrivances, produce an endless variety of objects. The collections made include a large assortment of the ancient stone implements and of the refuse from the lodge-shop sites which cover the prairie for miles around. A section of the pipestone stratum was secured including the full thickness of pipestone and several inches of the massive quartzite above and below. This section will be clamped together and cut and polished upon one side for exhibition at the World's Fair at Chicago.

The *Copper Mines* of Lake Superior yielded native or mass copper which was extracted from the rocks by the ancient aborigines and distributed over a large part of the continent. On Isle Royale, situated near the northern shore of the lake, thousands of the nearly obliterated pits are still to be found although many have been worked over by the whites who carried on extensive operations on the ancient site, finally abandoning the work about ten years ago. In cleaning out the old pits several masses of copper were encountered which had been uncovered by the aborigines who had striven in vain to break them up and remove them. The largest mass discovered weighed 12,000 pounds. The ancient mines were not deep, but consisted mainly of pittings, made in prospecting for masses of copper, exposed or partly exposed by glacial ice and afterwards covered by till and drift. Trenching discloses the fact that the old pits are filled with crushed rock, charcoal, bits of oxidized copper and innumerable stone hammers and sledges, the latter having been used in freeing the masses of copper from the inclosing rock. There are no indications of the working of copper upon the site although a few shaped pieces have been reported. It is highly probable that the masses of metal were for the most part transported to distant points to be worked up according to demand. The examination of these mines as well as of the pipestone quarries was made in June, 1892, and extensive collections were obtained for exhibition at the World's Fair at Chicago.

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ABORIGINAL QUARRIES OF FLAKABLE STONE AND THEIR BEARING UPON THE QUESTION OF PALÆOLITHIC MAN. By W. H. HOLMES, Bureau of Ethnology, Washington, D. C.

[ABSTRACT.]

THE quarrying of stone for the manufacture of flaked implements was carried on extensively by the American aborigines and the study of the quarry phenomena recently made is found to throw much light upon the nature of many rudely shaped stones heretofore classed as implements and placed in evidence as such upon most important quest ns. The partly worked implements rejected at various stages of the shaping processes because of defects in texture and fracture are found to correspond perfectly to forms that have usually been classed as palæo ithic because of their assumed close resemblance to European palæ olithic forms. It is shown that in America the conditions are such that no specimen can be safely assigned to palæolithic culture by its form alone. It further appears that nearly all the rudely flaked stones reported from the glacial gravels are identical with the failures left in roughing out implements in the quarries and shops and do not present those evidences of specialization that characterize the well established types of European palæoliths, the probabilities being, therefore, that they, also, are failures produced in the manufacture of more highly specialized forms and that they are not really completed implements. This view is further supported by the fact that the culture of the gravel-forming period of western America appears to have been neolithic and that the rude forms found so sparingly in the eastern gravels representing the same period may be the scattered refuse of neolithic implement makers who ventured down to the banks of glacial torrents to secure the raw material. Before this class of evidence can be safely employed in affirming the existence of a palæolithic period of culture, the observations must be multiplied until it is settled satisfactorily, first, that the objects found are *bona fide* implements and not mere refuse, and second, that they are the exclusive art product of the period they represent. Behind this is the question as to the reliability of the observations already made upon the occurrence of works of art of any kind in the gravels. The phenomena being geological and observed in the main by persons inexperienced in this science and that too before proper stress had been laid upon the need of absolute accuracy in every detail, the probability is that

a very large percentage of these observations is defective or erroneous. Taking the most favorable view of the existing evidence it is apparent that the existence of a palæolithic culture in America in glacial times is far from being established, and it is evident that until geologists unite with archæologists in observing the phenomena and by careful and long continued observations accumulate a large body of unimpeachable evidence, the question will remain unsettled.

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ON THE SO-CALLED PALÆOLITHIC IMPLEMENTS OF THE UPPER MISSISSIPPI.

By W. H. HOLMES, Bureau of Ethnology, Washington, D. C.

[ABSTRACT.]

THE discovery in Little Falls, Minnesota, of numerous objects of flaked quartz supposed to be of palæolithic age was reported by Miss F. E. Babbitt in the year 1880. In visiting the locality in 1892 I had the good fortune to be accompanied by Prof. N. H. Winchell, State Geologist of Minnesota, who had been over the ground with Miss Babbitt some years before. The site was, therefore, properly identified and Professor Winchell was present during the examinations made by me and freely expressed his approval of the conclusions reached.

The quartz-bearing bed occurs about midway in the gentle slope of a glacial terrace facing the Mississippi river and just above the present level of the water which has been raised about ten feet by a dam recently constructed at the falls below. I found numerous fragments of quartz projecting from the surface of the ground near the water level and at higher levels in the sides of a shallow roadway that led from the upper terrace to the modern flood plain below.

A trench was begun at the water level on the north side of the roadway and carried in on a horizontal floor nearly at right angles with the terrace front which here sloped back so gently that an advance of forty feet was made before the full height of the section, twelve feet, was exposed. The quartzes were very numerous on the level from which Miss Babbitt obtained her specimens but decreased as advance was made. They were found to occur, however, not only at this level but scattered throughout the full thickness of the deposits until an advance of twenty feet had been made and a depth of six feet had been reached. Beyond this the first traces of the normal glacial deposits were encountered and in these no quartz fragments were found. The quartz containing deposits are of recent formation being composed of materials derived from the edges of the crumbling beds above and are filled with the refuse of arrow making left upon the slopes and margin of the terrace.

The face of the undisturbed gravel beds encountered at about the twentieth foot rises more abruptly than the outer surface of the talus, and the latter deposit, as a consequence, thins out very considerably toward the top. The trench was carried about forty feet into the terrace and the examination was continued one hundred feet further across the upper surface by means of pittings at intervals of about twelve feet. Worked quartz was found upon the surface everywhere within a radius of upwards of a hundred feet from the initial point of the trench and also distributed through the surface loam to a depth of from two to three feet. This latter distribution is uniform from the surface to the full depth and could only have been brought about by disturbances of the surface by such agencies as the growth and decay, and the uprooting of trees, causes still operating in the region.

It appears as a result of these examinations that the worked quartzes are confined to the surface loams and to the heterogeneous talus gravels of the terrace, and that the shaped pieces are nothing more than the failures left by arrow-makers who may have occupied the spot at any period from glacial times down to within fifty years ago. The raw material was vein quartz obtained from the Pre-Cambrian slates exposed in the river bed.

The explanation of the unfortunate errors fallen into by the original observers is that the archæologist identified the works of art and the geologist the geologic formations, neither thinking it necessary to determine the vital point as to whether or not the works of art were really associated with the undisturbed gravels.

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BRIEF REMARKS UPON THE ALPHABET OF LANDA. By DR. HILBORNE T. CRESSON, 224 South Broad street, Philadelphia, Pa.

[ABSTRACT.]

THE Maya script, both in its hieratic and demotic forms, is the same as the higher grade of ikonomatic writing described by Aubim. The word hieratic applies to sculptured Maya glyphs, demotic to more cursive forms used by the ancient Maya scribes.

A Maya hieroglyph may be a single character, the meaning of which is expressed by the sound of the name of the thing represented; or it may have a number of components that convey by a similar method a series of ideas.

*Suggestions*:— The Maya scribe gave glyphs, whether simple or combined that carried out Landa's pronunciation of the Spanish alphabet by means of characters which stood for the sounds of the names of these letters.

For example: If Landa asked for H which he pronounced *átchay*, he would have been given the *H* or *há* glyph and the *Cha* glyph.

The alphabet being prepared by the author of this abstract, suggests that this method of procedure was followed out by the Maya scribes whom Landa employed. The alphabet will not be made public until it has been thoroughly tested; if it is correct it will stand—if not it will fall. Tests made with it place the Maya signs of orientation as follows:—Chikin, west (the sun bitten), Lakin, east, Tchaman, north, Nohol, south; this agrees with the new arrangement of Professor Thomas and the assignment of de Rosny.

It is further suggested that the decorations of the ancient Maya palaces are ikonomatic, as many of these designs are in form similar to the alphabet used by Cresson or variants of its arrangement.

The ikonomatic decorations of the palaces in question, if we may judge from photographs, are quite simple and some of them probably are derived from forms which have had their origin in the textile art, which, to use the words of William Henry Holmes, of the Bureau of Ethnology, "dates back to the very inception of culture."

The Cayman, *ixbáau* (Maya), appears on the head dresses of some of the divinities represented in the Codex Troano and in the sculptures of Chichen-itza, and the work of the scribe sculpture suggests that he may have been an important divinity. The Maya C and K may have been obtained from the graceful lines of this reptile's body. The outline derived from the delineation of the life-form suggested by the Cayman (Ixbáau, legarto de la mer), was probably used for the *Kan* glyph, for it suggests the graceful curves of the serpent's body. These glyphs having the phonetic value of C and K, so far as we have determined. Other forms derived from the Cayman are also to be noted, among the ikonomatic decorations of Chichen-itza. The eye and scales of the reptile also have a phonetic value as in the scroll glyph having the I or *vich* determinative — *ix* or itz.

The phonetic value of the representation of the scales of the Cayman is also *ix* or *sh*, and they are recalled by cross lines in a small glyph near the reptile's head in the example to which we refer in the Codex Troano and they are also shown in sculptured representations on the *ixbáu* head shown in the "*Portique de la Jeu de Paume, à Chichen-itza,*" page 314, Charnay's *Les Ancienne Villes du Nouveau Monde.*

The *sh* or *x* glyph in the author's arrangement may in fact be traced to certain animal characters, and so may the *chi* glyph (from *chi*, to pinch, bite) be traced to animal characters such as the pinching hand (of man), the tarantula and centipede claw, the cayman's mouth and its teeth—all of these glyphs being derived from the life-line in art in various stages of simplification and adapted to the limestone material in which the scribe sculptor carved his work on the vases on which he incised more demotic forms of script. From the *chi* hieroglyph has been derived *Chà*, *Chā*, or *Che*, *Cho*, *Chu*—it was the *Chi* glyph that suggested one of the compound characters in the Codex Troano to be *Chikin*—the west—"the sun bitten."

The figures of the Codex Troano seem to be composed of ikonomatic designs and the glyphs themselves frequently have a number of phonetic components to express their meaning. The same suggestion we think applies to the hieratic sculptures and glyphs.

Repeated allusions seem to be made in the ikonomatic decorations of the palaces of certain ancient Maya cities to Zamna or Itzamna the son of *Hunakbu*, and to *Cauac* who seems to have been the *Ek-Xibchac* or "the Male Leopard of the evening." Sculptured representations of this leopard-god are given in the illustrations, page 309, Charnay's "Les Anciennes Villes du Nouveau Monde," Chichen-itza. *Cauac* the *Cuch-haab* also appears in the upper division of the bas-relief at the left hand side of page 294 of Charnay's work, and also in the lower division, while *Kukulcan* occupies the centre, holding in his hand the *hohok* or noose, which in some cases is found around the feet of this divinity. *Cauac* (Cau-ek) again appears on page 293 of Charnay's work; the *Antennae* sign of the bee, characteristic of the *Cauac* glyph, is to be seen in front of the figure while the maize sign is attached to his head, the action of the hands suggesting the chief year bearer or *Cuchhaab* and the *bacab* who supports the firmament; below in the column are ikonomatic decorative glyphs suggesting *Cab* the earth, Há or water and the maize leaf—emblems of fertility, in which *Ikilcab* the bee assisted by mixing the pollen of *Ixim*. The large plate in Charnay's work to the right hand side of page 286 shows the left wing of the Temple at *Chichen-itza* and from its cornices project the ikonomatic representation of the so-called "Long nosed God" who figures repeatedly, even in demotic script. The *Chi* glyph and *ich* and *há* glyphs form his mouth, the K or *kan* glyph is the trunk, the large centre glyph at the same time repeats the suggestion, and the Z glyph and two medallions recall Kukuitz and Itzamna, while other components of this ikonomatic decoration suggest *Chi-Chen*.

Other suggestions in this respect might be made. What have been given are simply intended to indicate a new line of research to those interested in the subject—for whether the decorations of the ancient Maya palaces, their glyphs and other sculptures, eventually prove to be ikonomatic, which the writer of this abstract firmly believes they will, they have certainly never received the careful study which they merit, and to which the Bureau of Ethnology at Washington is now devoting especial attention by a study of the Maya language and of its graphic system both hieratic and demotic.

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COMPARATIVE CHRONOLOGY. By W J McGEE, U. S. Geol. Survey, Washington, D. C.

[ABSTRACT.]

CERTAIN so-called "natural time units" are recognized by primitive peoples and civilized men alike. These are derived from the motions of earth, moon and sun, and are commonly limited by means of conjunctions. They form the bases of calendars and chronology. History borrows these units and groups them into eras marked by events of real or imaginary import, such as the birth of nations, the beginning of dynasties, or more commonly the origin of religions. The study of living things shows that the life of the earth has not flowed as a steady stream in a constant direction, but has followed divergent lines and repeatedly risen into waves each culminating in a dominant type which afterward became subordinate or died out; and in this way a series of biotic ages has been recognized in biology and paleontology. These ages cannot directly be reduced to eras or cosmic time units. Geology teaches that the rocks of the earth are made up of formations each deposited during a more or less definite period, and these periods are combined in a system of chronology characterized by vast

length of the units or time elements. The cosmic units, the biotic ages, and the geologic periods are incommeasurable, but are approximately reducible to a common standard by means of certain coincidences or conjunctions. This reduction is greatly facilitated by certain recent American investigations; and it is now practicable to express geologic time in terms of the historical chronology more accurately than ever before. The reduction is stated in tabular form and illustrated graphically by means of diagrams. The estimate of the duration of different geologic periods thus determined has an important bearing on the question of the antiquity of man.

The paper was illustrated by several large charts. [The paper is printed in full and the charts reproduced in the American Anthropologist for October, 1892, Vol. v, pp. 327–344].

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THE EARLY RELIGION OF THE IROQUOIS. By Rev. W. M. BEAUCHAMP, Baldwinsville, N. Y.

[ABSTRACT.]

WHILE primitive American beliefs are of interest, we are not sure how early they were affected by civilized influences, but the Iroquois religion has greatly changed. It is included in three periods: primitive, that affected by the missionaries, and that of the Peace Prophet. It is doubtful whether they had a definite idea of one Great Spirit when first known, and the account of the creation is confused. The Okkis, in their estimation, were good, rather than evil spirits. All men had two souls, and this affected their burial rites. Sacrifice was an occasional act, but there was little system in their worship. Dreams were of the most importance in this, and are still prominent. Witches were feared and abhorred, and animals were venerated. The Peace Prophet gave them a definite system a century since.

[This paper is published in full in the American Antiquarian, Nov., 1892.]

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EARLY INDIAN FORTS IN NEW YORK. By Rev. W. M. BEAUCHAMP, Baldwinsville, N. Y.

[ABSTRACT.]

THE difficulty is great in getting a full list. All villages were not fortified, and were frequently removed. There are several large groups, besides smaller ones. The form and construction of earthworks varied, and these generally preceded stockades, which were of four kinds: single, double, triple, and quadruple. The ditch was less defensive than incidental, and in stockades post-holes were not always used. Many examples of both modes of defence still remain, and Squier's estimate of their numbers was a fair one. According to the catalogue of the Bureau of Ethnology defensive works belong mainly to the northern U. S., especially near the great lakes.

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PREHISTORIC EARTHWORKS OF HENRY COUNTY, INDIANA. By T. B. REDDING, New Castle, Ind.

[ABSTRACT.]

THERE are, in the county, ten mounds surrounded by enclosures; there are eleven mounds that do not seem to be surrounded by enclosures, though some of them may have been; there are six enclosures in which mounds do not appear, or have been obliterated; there are twelve, or more, doubtful mounds which have not been sufficiently explored to determine their real character; there are three doubtful enclosures. The mounds range from 20 to 150 in diameter; the enclosures from 100 to 250 feet in diameter. There are also numerous burial grounds in gravel and sand banks of the county where skeletons of an unknown race have been found. Many of these crumble on being exposed; others are in good preservation.

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ON SOME PREHISTORIC OBJECTS FROM THE WHITEWATER VALLEY. By AMOS W. BUTLER, Brookville, Ind.

[ABSTRACT.]

IN a small collection of specimens are several of considerable interest. One a hematite hemisphere from near Mt. Carmel, Franklin County, Ind., is one of very few hematites from the county. A pestle from Wayne Co. (?) is of soft hematite and evidently has been deposited for some time in water so that the iron has been extracted and deposited about the implement as "bog iron ore."

An ornament of galena, found near "Twin Locks," four miles from Brookville in a plowed field, appears to be encrusted with carbonate of lead.

An arrow head from Brookville seems to have been worked over cutting down the original size of the implement and having peculiar flanges at the barbs.

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SOME INDIAN CAMPING SITES NEAR BROOKVILLE, INDIANA. By AMOS W. BUTLER, Brookville, Ind.

[ABSTRACT.]

IN the vicinity of Brookville, Ind., on the Whitewater river, there are many Indian sites. Some were doubtless nothing more than camps, others were occupied for a longer time, several in all probability mark the location of villages. Within historic times some of these sites have been occupied and near some of them agriculture was carried on to a limited extent. Of historic sites the following are noted: One near Templeton's Ford, three miles north from Brookville in the valley of the East Fork of Whitewater. One two miles west of Brookville, just beyond the "Boundary Hill, in the valley of the West Fork of Whitewater. One in the northwestern edge of the town of Brookville. One in the southern part of that town upon the highest alluvial terrace between the two rivers and overlooking their junction, and one four miles south of Brookville, where Little Cedar Creek empties into the Whitewater.

Of prehistoric sites there are many but it is only proposed to call attention to a few situated near Brookville.

On the east side of Boundary Hill, on a little bench. which has been for years occupied as an orchard there is one which shows evidences of long occupation.

Just south of this, across the river, is another on the land of R. M. Stoops.

In the northwestern part of Brookville, upon the highest terrace in the town, is another site which also shows evidence of considerable occupation. North of Brookville in the same section upon the land of my father is a bench of glacial clays and gravels where are the sites of two camps. Southeast of Brookville in Section 33, near the group of mounds in that section is a site that is quite noticeable.

East of this, over a half mile, on Little Cedar Creek is a site which seems to have been occupied extensively and with it appears to have been a workshop. Across the Whitewater river, from section 33, upon the land of O. M. Meyncke, another site is noticeable.

One thing of interest is that the most extensive sites were located near some of the finest springs in the valley.

Drawings and specimens were used to illustrate the paper.

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ON THE EARTHWORKS NEAR ANDERSON, INDIANA. By AMOS W. BUTLER, Brookville, Ind.

[ABSTRACT.]

A notice of the works with a statement of the plans proposed for their preservation. Illustrated by a map and photographs.

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ANVIL-SHAPED STONES FROM PENNSYLVANIA. By DR. D. G. BRINTON, Media, Pa.

[ABSTRACT.]

NUMEROUS stones about the size and shape of a blacksmith's anvil have been found in eastern Pennsylvania, in localities and relations which have led many to believe they are aboriginal relics. Some of them appear to show signs of chipping, others do not. Even if natural forms, they may

have been collected and employed in utilitarian or ceremonial customs. A specimen is exhibited, and its possible application in these directions discussed.

The first who brought these stones to the attention of scientists was Mr. Charles Laubach, and their investigation has been chiefly due to Mr. H. C. Mercer, who furnished the example shown.

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PEBBLES CHIPPED BY MODERN INDIANS AS AN AID TO THE STUDY OF THE TRENTON GRAVEL IMPLEMENTS. By H. C. MERCER, Doylestown, Pa.

[ABSTRACT.]

I wish to call the attention of the Section to these sandstone flakes with a pebble surface, and these chipped river pebbles, the smaller of which belong to the type generally referred to as "paleolithic" in the United States.

With one exception (the large one from Fry's Run on the Delaware,) they represent that region of the Upper Susquehanna lying between the glacial moraine at Beach Haven on the eastern branch and the mouth of the Juniata, the gravel beaches and hard clay banks with relic-bearing strata on shore and island, at Saw-mill creek, Mahoning, Pulaski, Johnson's creek and Hall's island.

[A drawing showing the geological structure of the river bank and the position of the specimen was exhibited.]

That these chipped stones all fell from the discolored implement-bearing stratum in the upper part of the bank we need not positively assert, nor go into the question of the comparative absence of Indian remains on the surface of the fields above or the age of the loam stratum that overlies the relic belt, whether it is the slow growth of vegetable mould, or the alluvium of comparatively modern freshets. Suffice it to state the important fact, that here lie the stones in question strewn about in every case with potsherds, arrowheads, net sinkers and pitted stone hammers.

When we find these conditions repeated six times at the places I have named, there is no guesswork in the inference that the chipped pebbles were the work of men who, knowing the use of wild hemp and rope-spinning, caught fish in nets; who had quarried jasper *in situ*, for it is hardly possible that all the black arrowheads and chips on the beaches came from river pebbles of that material; who understood the potters' art and who made polished celts, spear heads of finished workmanship, and banner stones.

Let us look at the specimens and let us class with them this pebble from which we believe a "Tesh-o-a" has been skilfully chipped, found lying amongst them. And here is the "Tesh-o-a" itself. We know that it is a knife, for the Shoshonees, who fashion and use knives like this, have told us so—a cutting implement with fine sharp edge all around it, knocked at one blow from a pebble. So useful, so easily made, so ready to hand wherever pebbles lie together on the earth, that the modern Indian, equipped with gun, iron knife and government blanket still uses it, as he would use the fire drill at a pinch, as a thing elemental, common to the life in nature, as one of those ancient secrets not to be forgotten save by the artificializing of all the conditions of his life.

But it is of these other flake knives that I wish particularly to speak, because though made like the teshoa, at a single blow, they are obviously simpler, because having been knocked from the edge rather than the middle of a pebble, they have required less skill and force in the concussion that produced them.

Scattered about among the "teshoas" and stone hammers, with their cutting edges similarly dulled by well weathered marks of usage, is it easy to help believing that they were made for the same purpose? And that these large chipped masses, lying with hammerstones hard by, sometimes showing no signs of use on their cutting edge and often weighing fifteen to twenty pounds, were anything but the nuclei from which these knives were flaked? Yet, while allowing this, that the chips and not the nuclei were, in some cases, the real implements sought after, we realize at the same time that the first few blows of stone upon stone, pebble upon pebble, whatever the end aimed at, must have produced strikingly similar results, that many of the chips were not knives, and many of the nuclei were not knife-material.

Argillite and sandstone blades were made on the Delaware and Susquehanna from river pebbles at work sites like Point Pleasant, where the flakes and cores though resembling these, had a different meaning. There were jasper quarries at Durham and Saucon creek where the chief story of the refuse may be that of blade making. Indeed the savage probably chipped stones for many purposes as yet undreamed of.

Let us only insist that here were six cases where the stone chippers' object was to make flake-knives, and that at these sites one distinct process has been added to those already studied and classified as illustrative of prehistoric life in America, a process, which like the art of making "teshoas," that seems but a refinement of it, may well have been too useful, too handy, too adequate to the needs of savage life ever to have been discarded by the North American in his stone age.

On the other hand we may ask the important question, whether the process was not too simple and rudimentary ever to have been preceded by any other process.

If there was a time when man first chipped one stone with another —and who can deny it?—how shall we imagine him proceeding straightway to make an implement at ten blows, when he got one at one, making a "paleolith" before he knew that the first chip therefrom would cut? And can we easily help regarding this chip-knife next only to the hammerstone that made it, as the type of the most venerable of all stone implements, the first cutting tool of stone fashioned by the hand of man to arm himself for his early conflict with the forces of nature.

In a word supposing the first comer to the shores of the Delaware to have been paleolithic man, it is not easy to see how he could have avoided making specimens like these.

But these flake-knives, we may infer, were not always chipped from large boulders any of which is a heavy burden for a man.

Take a smaller pebble and knock a few chips from it, for the same purpose. Have you not in the act hit upon another way of accounting for certain of the forms from Trenton? And are you not driven to seek for some clew outside the shape of your specimen, in attempting to assign for it a relative age?

Now we know that these particular flake-knives and cores are as modern as pottery and net-sinkers, in the sense that the specimens from the Durham and Flint Ridge quarries are modern, and that those from Piney Branch, which they resemble, are modern, and let us find, as I have found, "paleoliths" or "turtlebacks" of argillite, sandstone, quartzite and jasper, which may be classed as modern "failures," "blocked out blades" or knife material as the case may be, on the Delaware at Point Pleasant, Ridges Island, Gilmer's Island, Hickory Run, Gallows Run, and Upper Blacks Eddy, but by no means, let us push the inference too far; for what proof or even probability is there that precisely similar objects are not to be found in a deeper geological horizon in the same valleys where, disassociated with tokens of the later Indian, they represent the work of men preceding him by thousands of years?

What if the so-called "paleolithic" form must be finally given up as a type? What if it represents no particular period whatever in the past of the American stone age?

Once forced, as we are, to admit that a man inhabiting the valley in glacial times could hardly have avoided chipping stones like these, we realize that there are years of careful search ahead of us, that there are scores of sand pits, railroad cuts, wells and falling banks to be closely examined, that there are thousands of dollars to be spent in the days' wages of laborers digging trenches on the shores of the rivers that drained the great glacier, before we venture to conclude and be positive. Since the one thing which can finally identify such stones as the handiwork of a River Drift man, whether "paleolithic" or "neolithic," or settle their relative age beyond a doubt, is not their shape, or waterworn appearance, their association or disassociation with supposed later Indian remains, or their classification with flake-knife material or half finished blades, whether at Durham, Flint Ridge, or Piney Branch, but their stratographic position.

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ANCIENT EARTHWORKS IN ONTARIO. By C. A. HIRSCHFELDER, U. S. Consulate, Toronto, Canada.

[ABSTRACT.]

THE author described a number of forts which he has surveyed in the old Huron country, which was located in Simcoe County, Province of Ontario, Canada. With the exception of a peculiar hold in South Villia township, the various earthworks appear to have been made and used solely for defensive purposes. Some are on a large scale and most of them bear evidences of considerable age.

Nearly all the forts of the Huron district are similar in construction, but there are several in other parts of the Province which are unique; one in particular, situated in the county of Elgin, bearing a resemblance to works described by Squier and Davis. This fort is of peculiar interest from the fact that the author believes it to be a solitary monument of the farthest eastern point inhabited by the ancient mound builders. The fort measures 428 by 325 feet, and as evidence of its age might be cited the fact that one tree growing on the embankment measures 11 feet 3 inches in circumference.

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EVIDENCES OF PREHISTORIC TRADE IN ONTARIO. By C. A. HIRSCHFELDER, U. S. Consulate, Toronto, Can.

[ABSTRACT.]

IN connection with this paper the author showed specimens of shells (*Pyrula* and other genera) as evidence of a traffic having been carried on between the Indians of the North and those of the South, extending over 2000 miles These shells have been found in some of the oldest ossuaries discovered in Ontario.

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OBSERVATIONS UPON FORT ANCIENT, OHIO. By SELDEN S. SCOVILLE, M.D., Lebanon, Ohio.

[ABSTRACT.]

THE author gives the topography of the ground at the east part of the fort and that extending to the northeast, on which the guarded roadway formed by the two parallel walls is situated. This, it is believed, has not hitherto been satisfactorily done by writers on Fort Ancient. The adaptation of the works here, to the surface of the ground and the water courses shows good judgment, and the planning and execution of the work could not well be surpassed. The line of high embankments crossing the neck of the peninsula reveals the same wise calculation in all its features. Instead of taking a direct course, it forms two curves in order to secure the natural protection from two small streams which arise near the middle of the neck of the peninsula, and run in opposite directions, one to the north the other to the south. The sections of wall that form this line are six in number and taken by themselves are perfectly straight. The changes in direction of the line occur at the openings or gateways. It will be seen that by adopting this plan time and labor were saved. These high sections of wall had originally flat or level summits, and their elevation was never but a trifle greater than at present. The wear has been principally from the angles at or near the top. Their shape was that of an elongated truncated pyramid with a side slope of 50 or 55 degrees.

Attention is directed to the large area of level ground inside the fort, which should be considered in connection with the crescent-shaped wall in this part of the fort. This crescent, it is claimed by the author, is but the remains of a complete circle that once existed here. The larger part of the earth circle was removed when the main works were constructed to extend the area of level ground referred to. The portion remaining is 270 feet in length. The complete circle was about 280 feet in diameter, and had probably but one passway which is plainly visible at the present time in the middle of the part remaining.

The gateways in the walls of the fort are difficult of explanation, in view of the works having been constructed for defensive purposes. We find no evidence that they were provided with means of closure in times of danger. We may look at all the circumstances surrounding the people who inhabited the place and the object they had in view in fortifying their town or city, and we find no very satisfactory explanation for so many gateways. They no doubt served as pass-ways for the citizens, and most likely were of some strategic value.

Is there any evidence that all the earthworks at Fort Ancient were not constructed at the same period of time? This question the author believes has never been mooted. And he gives reasons for believing that the long enclosing walls were constructed at a much later date than the parallel walls and mounds.

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SINGULAR COPPER IMPLEMENTS AND ORNAMENTS FROM THE HOPEWELL GROUP, ROSS COUNTY, OHIO. By W. K. MOORKHEAD, Xenia, Ohio.

[ABSTRACT.]

A brief account of some of the axes, plates, sheets, stencil-like figures, ornaments, combs, bracelets, spool-shaped objects, headdress, and other objects made of copper found in a large tumulus in Ross Co., Ohio, during an exploration carried on for the Ethnological and Archæological department of the World's Columbian Exposition.

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THE RUINS OF SOUTHERN UTAH. By WARREN K. MOOREHEAD, Xenia, Ohio.

THE first of March, an expedition consisting of eleven men left Durango, Colorado, for the purpose of examining the ruins of southern Utah. The members of the party were aware that the more important ruins upon the San Juan River and its tributaries had been explored by Messrs. Jackson, Holmes and others. Hence, we desired to cover such territory as had not been entered by the government surveys and to examine such ruins as private individuals had hastily viewed. In this paper particular attention will be called to the work done along the Colorado river and its side cañons.

In taking a general review of the San Juan country, one observes two classes of ruins,—the boulder dwellings, and houses of hewn stone. One might subdivide the hewn stone structures according to location and say that they occupied caves in the cañon side, prominent points upon the edge of cañons,—or, when located in fertile mesas, took the form of large compartment houses,—commonly known as pueblos. The boulder ruins invariably occupy the mesa and are not found upon the cañon bluffs or in the cañons themselves.

If we mistake not, these facts were noted by Messrs. Jackson and Holmes. One might go still further and say that all the hewn stone ruins represented the same architecture, whether located in the caves or upon the mesa, whether comprising one or two rooms or several hundred rooms.

Upon reaching southern Utah a survey finds very rich material for exploration. Few individuals have ever visited the ruins of Epsom Creek, Cottonwood Creek, or the McCombs Wash.

Among the ruins in the main cañon of the Colorado, Mr. Chas. MacLoyd is the only person who has carried on extensive work. He has spent two winters in making photographs and drawings and in collecting objects buried in the ruined houses. Although he was accompanied by a number of men, he found the ruins so extensive that he was able to visit but one-third of them. Many small cañons extending back from the Colorado two or three miles, ended in semi-circular amphitheatres, with sides ranging from two to five hundred feet in height. Such gorges are called box cañons. A small trail barely wide enough to allow a person to descend on foot, leads from the mesa into the cañon. Upon descending, one finds the caves literally filled with buildings of various sizes. In caverns having a dirt floor, there are seldom stone buildings, but instead, a most singular and unusual type of dwelling. Upon inspecting some of the caves, stone slabs four or five feet across were seen upon the surface. Perhaps the sands and dust, which the winds had swept within, half covered these stones. Upon removing them openings two or more feet in diameter were disclosed leading into dome-shaped cavities. It is not without difficulty that a person is able to lower his body into the dark uninviting depths of the cave.

The chamber had the appearance of a bell, small at the top and large at the bottom. The rooms averaged six feet in depth and seven in width at the bottom. There are as many as twenty of these rooms in one cavern. Many of them penetrated through the clay and were excavated into the soft sandstone beneath. Small doors at the sides frequently led from one to another so that a whole series of ten or fifteen rooms would be connected. Some of the smaller underground rooms were used as granaries, and several were discovered filled with seeds and corn. Skeletons were frequently found in the rooms accompanied by textile fabrics, deer-skin garments, flint implements, etc. In no instance was pottery found in the underground rooms. The cañons are so dry that everything used by the inhabitants of both cave and cliff dwellings was preserved almost as perfectly as the day it was buried. For instance, the following were obtained: beautiful feather-cloth robes and head dresses of the smallest feathers, rendered mouse colored by age; pieces of spindles and cotton fabric in various processes of weaving; cotton seeds and cotton cloth garments, many of which were painted in fanciful designs; buckskin robes, on the inner side of which were picture writings, similar in character to the winter coats of the Sioux. Bone, obsidian and flint cutting-implements, mounted in original handles, stone spears, with the shafts six or eight feet in length, basket work, blankets, pottery and many other objects and implements such as were used in the everyday life of the savage. The most interesting and valuable part of the collection were the mummies. They comprised some twenty men, women and children wrapped in feather cloth, buckskin garments and cotton cloths, many of them with sandals still upon their feet.

The atmospheric conditions for the preservation of these mummified bodies were exceedingly favorable. The skin remains dry upon the face and other parts of the body. The eyebrows remain intact, the lips seem rather full, the hair is still attached to the scalp, the larger muscles of the body are all preserved, the nails remain upon the fingers and toes, and the weight of the entire body is about twenty pounds. The mummies as found in the wrappings were three and a half feet in length. The limbs were doubled and the knees drawn nearly to the chest. The friends of the deceased removed the heart, lungs, bowels, and other internal organs before burial. This is plainly shown by an incision in the abdomen of each subject. Children have been occasionally found in the arms of adults, presumably their mothers.

Small squashes, gourds, beans, corn, and cotton seed occasionally accompanied the interment. Numbers of singular objects have also been found. For instance, bundles of feathers, small strands of cotton rope, raw-hide thongs, crutches, medicine wands or sticks two or three feet in length with the claws and teeth of animals, beaks of birds, pieces of obsidian, etc., tied to one end. Baskets usually covered the head of the mummy. Frequently the door of the room in which the mummy was buried had been walled up. Occasionally a burial occurred in an ash-heap in the rear of a dwelling.

During our journey we covered some sixteen hundred miles of territory, and in order to be more expeditious, split the party into two sections. Considerable excavating was done in the cemeteries in the valley and mesa ruins. The graves presented a uniform appearance. They could be divided into two classes, those skeletons found five or six feet deep occupying hollow stone vaults, those but two feet from the surface buried in the sand. Beautiful pottery, bone implements, minute arrowheads, bone spoons, beads, and shells accompanied the grave burials.

We found every river and creek literally lined with boulder ruins and small pueblos. The ruins did not exist, as in the Ohio valley, every few miles: they actually were continuous. In our opinion, no section of the country can be found where an institution could make larger collections in a short time in southern Utah. For instance, up Cottonwood creek, fifty miles north from the Mormon settlement, there is a section about twenty miles square, containing a great many caves and valley ruins, which were practically unknown at the time of the government surveys from

1876 to 1880. The larger of these caves contain good springs. Several large cemeteries and pueblos occupy the surrounding plain.

Some very interesting facts are obtained from the explorations of the ruins. No copper or metal of any kind has been found in the cliff houses or in the caves. All cliff houses and dwellings upon the edge of the cliffs were built manifestly for defence. The cliff houses themselves, whether large or small, have but one main entrance. That entrance faces the cañon. Each room contains a number of port holes pointing in every direction. The larger rooms frequently contain as many as twenty or thirty of these port holes, all of which are neatly and smoothly plastered, so that an arrow may be conveniently discharged through them.

In some of the stone buildings and in the caves, turkey dung covers the floor to a depth of two or three feet. Upon the walls in the rear of houses are usually hundreds of sculptures and rude paintings. Many, many times the turkey and the wild goat are shown in the pictographs. Hence, we conclude that aside from what was grown by means of irrigation, primitive man in the San Juan country lived largely upon the goat and the turkey.

No metal has been found in any of the ruins, and such caverns and pueblos as we saw bore no evidences that the builders were associated with the Spaniards. Our observations led to this conclusion. The region was inhabited by two and possibly three tribes more or less alike in manner of living, in agriculture, in pottery making, in weaving, and in other arts. They differed in unimportant matters. For instance, the Cliff and Cave dwellers made mummies of their dead, the Valley dweller placed his in graves. One flattened the skull by artificial pressure, the other did not. One lived in inaccessible fortresses, the other dwelt upon the plain. It seems to us that these differences are not sufficient to warrant us in setting them apart from each other as distinct and separate peoples.

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A FEW PSYCHOLOGICAL INQUIRIES. By LAURA OSBORNE TALBOTT, Washington, D. C.

[ABSTRACT.]

A DEEPER insight into the child's mind seems to be needed before much can be accomplished in the way of a true and satisfactory education.

In studies in anthropology, observations upon the evolution of the human mind and its results, are of the utmost importance.

Great interest attaches to the different degrees of progress made by the human subject at different periods and in different countries during past ages.

It is the mental vision or that power popularly known as the imagination which has been most active among the aborigines, and which has produced their quaint folk lore, and characteristic designs and beliefs. While striv-

ing to unravel the mysteries of the savage mind, and consequently of the development of our race, may we not find it advisable to give more study and attention to the inner workings of the child mind of the present day?

In our daily intercourse with our fellow human beings, no more important factor is to be noted in its actions and results upon the welfare of mankind, than that power of the mind which sees visions, or conceives new ideas from materials already existing in the mind.

There are undoubtedly numerous points of view from which this subject can be discussed, the present object is far from philosophical, but simply to urge a few practical inquiries as to the manner of directing the awakening powers of the child mind that may save our youth from the mistakes of a misguided imagination.

The imagination, or the power of mental vision, is the faculty, par excellence, upon which religion, art and commerce depend for their existence; banish the results of imagination from the world and what would be the condition of society? All the best things of our civilization would disappear and we should return to a state of barbarism. For unless the mental vision is aroused to receive impressions, no more effect will result than when the bodily eye is closed to impressions from physical objects. This condition of the mind which we term imagination has a close companion in the reasoning faculty, and the question arises; Which is the superior? In the little child the power to see visions is as great, if not greater, comparatively, than in the grown man. A lonely child will fill the room and vacant chairs with pleasant companions and derive great enjoyment from their imaginary conversations.

Thieves, knaves, magicians, juggling politicians, orators, and all classes of persons who desire to control the wills and energies of their fellow men understand in some degree the utility of diverting the imagination.

Even various systems of religion have sought to attract their followers by working upon their imaginations through artistic rites and ceremonies. Physicians often depend upon affecting their cures through the imagination.

To educate this power of mental vision aright would be soon to explode many of the popular isms, and fashionable beliefs of the day, and establish society on a surer and firmer foundation.

Certain teachers have acquired the power of awaking early in the youthful mind the power of insight. Why was Dr. Hopkins such a famous teacher? Was it not his method by which he aroused the thinking powers of the boy, and, by careful leading, opened his mental vision to a broad and expansive view of his fellowmen and of the universe?

This is the need of all of our children of the present day, to be strengthened in their mental powers, particularly in their imagination, and if the teacher has not a realization of this necessity, then public opinion or school overseers should see to it that freer exercise of the mind with references to practical affairs of life and a more generous culture should be given to the pupils. Investigations should be increasing, and at the same time unfelt by the child itself, in order to keep the imagination firm and strong. In France experts who do not instruct are employed in the schools to go about among the children and, by association and detection of idiosyncrasy, strive to strengthen the power of each child's mental activities in such directions as shall make them most useful in active life.

Is it not more individual attention our children need and more careful insight exercised over their mental development, at the same time permitting greatest freedom of mental growth, and not the herding of children with all their inherited tendencies, by the hundreds under the care of a few teachers, who have no time, strength or thought to attend to the peculiarities of individual development?

The mental powers seem to undergo as many changes in their growth from infancy to maturity as do the physical powers.

Those persons, in whom well-trained power of mental vision has been attained, have been of inestimable benefit of mankind. Theodore Cuyler, Oliver Wendell Holmes, Emerson and Macaulay, all peculiarly good thinkers, have understood very clearly the value of this mental vision, and seemed to hold it well in hand for the benefit of mankind.

Greater power of mental vision would soon bring men to understand each other's situation better, and sooner unite mankind into a perfect universal brotherhood.

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DEMONSTRATION OF A RECENTLY DISCOVERED CEREBRAL PORTA. By CHAS. PORTER HART, M.D., Wyoming, O.

[ABSTRACT.]

THIS paper consists of a few observations, accompanied by a series of photographic views, of a portion of the brain which has until recently escaped microscopic examination.

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PUEBLO MYTHS AND CEREMONIAL DANCES. By FRANK H. CUSHING, Bureau of Ethnology, Washington, D. C.

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AN ANCIENT HEARTH IN THE STRATIFIED GRAVELS OF THE BANKS OF THE WHITEWATER RIVER, IND. By AMOS W. BUTLER, Brookville, Ind.

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EXHIBITION OF A SKULL OF A PIG, FOUND IN OHIO, HAVING A FLINT ARROWHEAD IMBEDDED IN THE BONE. By Prof. E. W. CLAYPOLE, Akron, Ohio.

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PLAN OF THE RUINS OF TIAHUANACO. By A. E. DOUGLASS, Harvard Observatory, Ariquipa, Peru.

**Involuntary movements.** By Prof. Joseph Jastrow, Madison, Wis. [To be printed in Popular Science Monthly.]

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**Exhibition of pottery from a mound on the banks of the Illinois river, near Peoria, Ill.** By Dr. J. Kost, Adrian, Mich.

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**A definition of anthropology.** By Prof. Otis T. Mason, Curator of Ethnology, National Museum, Washington, D. C.

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**The department of ethnology of the World's Columbian Exposition.** By Prof. F. W. Putnam, Chief of the Department, Cambridge, Mass.

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**Exhibition of a model of the serpent mound of Adams co., Ohio.** By Prof. F. W. Putnam, Curator of the Peabody Museum, Harvard University, Cambridge, Mass.

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**Report of committee on international congress of anthropology.**

The committee appointed by Section H to consider and report upon the subject of an International Congress of Anthropology at Chicago during the World's Columbian Exposition report as follows:

They believe that a Congress of Anthropology should be held and that the Congress should hold a session for one week, meetings occurring daily from Monday to Saturday inclusive; the meetings to be in the mornings, leaving the afternoons free for examination of the interesting material at the Exposition.

The Congress to be divided into at least three sections, as follows:—a Section of Physical Anthropology, a Section of Ethnology and Ethnography, and a Section of Archæology.

The Executive Committee of the Congress to consist of the President and Secretary of the Congress, the President and Secretary of each section, and three members appointed by the Committee of Anthropology of the Congress Auxiliary of the World's Columbian Exposition.

The time of the Congress to be the week beginning on the Monday following the meeting of the American Association for the Advancement of Science for 1893 (or Aug. 29 to Sept. 3 both dates inclusive).

A permanent committee of five persons from Section H of the American Association for the Advancement of Science to be appointed to carry out the plan herein suggested.

The endorsement and coöperation of the American Folk Lore Society and of the American Psychological Society to be invited by the Committee.

For the Committee,

FREDERICK STARR, Secretary.

The Section accepted the report of its committee and appointed the following as a committee with full powers to carry out the plan proposed and to fill vacancies and to add to their number if desirable: —

D. G. Brinton, F. W. Putnam, W. H. Holmes, Joseph Jastrow, Frederick Starr.

Upon the Council of the Association requesting each section of the Association to appoint a committee to coöperate with the World's Congress Auxiliary in the organization of such congresses as pertain to the sciences of the several sections, the above-named committee was again appointed as the committee requested by the Council.

At the following General Session of the Association, on the recommendation of the Council, this Committee, with the committees of the eight other sections, was made a General Committee of the Association to coöperate with the World's Congress Auxiliary for the purpose named.

WM. M. BEAUCHAMP,

*Secretary of Section H.*

# SECTION I.

# ECONOMIC SCIENCE AND STATISTICS.

## OFFICERS OF SECTION I.

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*Secretary.*

HENRY FARQUHAR, Washington, D. C.

*Member of Council.*

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ADDRESS

BY

# LESTER F. WARD,

VICE PRESIDENT, SECTION I.

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## *THE PSYCHOLOGIC BASIS OF SOCIAL ECONOMICS.*

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THE object of my remarks this afternoon shall be to emphasize the distinction between that system of political economy which is based upon the actions of the human animal and that system which is based upon the actions of the rational man. The former is the prevailing system of the schools as taught under varying aspects by the physiocrats, Adam Smith, Ricardo and Malthus. Its underlying principles are set forth in the writings of Herbert Spencer and constitute the warp of modern individualism. The latter has from time to time been dimly foreshadowed by certain writers but has never taken any scientific form except in a little known work by the present writer.[1] Although its distorted image is reflected in numerous more or less obnoxious forms from the mirror of public opinion, its real shape is quite unfamiliar to the greater number even of the best informed persons.

Auguste Comte recognized the influence of mind in society and placed psychology where it belongs in his hierarchy of the sciences, but he refused to give it the rank of a science distinct from biology and classed it as a department of that science, calling it "transcendental biology." Nevertheless, in his discussions he gave considerable weight to it, laying stress on the elements of prevision and the control of social phenomena. Spencer, on the contrary, while he treated psychology at length and assigned it the same

[1] Dynamic Sociology. D. Appleton & Co., New York, 1883, 2 vols.

position that Comte did, failed to make it the basis of either his sociology or his ethics, both of which in his system rest directly upon biology. His psychology, therefore, which, indeed, was written before his biology and largely from the standpoint of metaphysics, stands isolated and useless in his system of synthetic philosophy.

The question is whether the phenomena of social, political, and industrial life rest primarily upon or grow chiefly out of the facts and laws of biology or those of psychology. It became early fashionable, in the name of science, to treat the uniformity and invariability of natural phenomena displayed in the astronomical and physical world, as extending also to animal life including the operations of economic forces in society. The correctness of this view, considered in the abstract, cannot be questioned, but the economists of that time did not sufficiently understand the nature of such complicated phenomena to make them the basis of a political or industrial science. The time has scarcely come as yet when we can do more than carefully feel our way along this obscure path; but the flood of light, which modern science since Darwin has shed upon the whole domain of biology, has not only pointed out the erroneous character of the prevailing mode of reasoning, but has shown at least one, and this the most fundamental source of the error which pervades it. This consists in practically ignoring the existence of a rational faculty in man, which, while it does not render his actions any less subject to true natural laws, so enormously complicates them that they can no longer be brought within the simple formulas that suffice in the calculus of mere animal motives.

While the subject, as thus outlined, is primarily a psychologic one, viz., that of determining the true rôle that mind has played in the industrial history of the race, the question at issue is essentially an economic one. There are two distinct kinds of economics, biological economics and psychological economics—the economics of life and the economics of mind. That is to say, there are two kinds of economy which it is of the first importance sharply to contrast, the economy that prevails in the animal world, in the domain of life, in organic nature generally, and the economy that prevails in the human sphere, in the realm of mind, in the domain of reason.

Every one is now familiar with the general nature of animal economics. It is the survival of the fittest in the struggle for existence. It is the mere physics of life. Just as in the physical world and the great clash of mechanical forces, the superior overcome the inferior and what we see is the resultant product of the struggle, so in the great struggle of life the forms that exist are such and only such as were able to survive the ordeal. But in biology the forces are the various tendencies to grow and develop including animal appetites, wants and desires. These are ever seeking satisfaction, and only their relative feebleness can prevent them from attaining it.

It was formerly supposed that organic nature was economical of its energies. The facts early observed, that every organ is adapted to some function and that every creature is fitted for the place it inhabits and the life it leads, were supposed to indicate a state of perfect harmony in the entire machinery of nature involving the maximum economy. Such misinterpretations were widely inculcated by optimistic writers and came at length to permeate the thought of mankind. The political economists seized upon them and made them the basis of their systems, and even the great philosophers were and continue to be affected by them. Still, nothing is now better known than that the great biologic law, instead of being economical, is extremely wasteful of energy. It is indeed true that everything that is made by nature is adapted to some function or use. This follows from the genetic method of evolution. Everything that exists is pushed into existence by a *vis a tergo*. Nature only works through efficient causes. The universal life force is perpetually creating new organs and new forms, and these must be adapted to their environment, otherwise they cannot even be brought into being. But this adaptation need only reach the minimum stage. If it is sufficient to insure continuance the end is attained, though higher degrees are always being aimed at. The means, however, through which the world is kept peopled with life are far from being the most economical conceivable. They often seem to be the least economical conceivable. They are just such as all the circumstances of each case combine to produce. The cost of accomplishing a given end is wholly immaterial from a purely biological standpoint. The extravagance of nature has long been perceived even by political economists but they have failed to see that its admission was fatal to their physiocracy. Malthus showed that but for premature deaths, population would increase beyond all bounds, and he also foreshadowed Darwin's law of natural selection by proving that this mortality was really caused by competition and the struggle for existence. We now know that in the animal and vegetable world, but for this wholesale destruction of those that have been born, any one species would soon overrun the earth. But the cost of bringing forth one of these unfortunate beings that are destined to perish at some early period in its history is as great as that of bringing forth one that is to reach maturity and contribute to the perpetuation of the species. Consider then the enormous waste involved in this method over a method which should only bring forth the number necessary to maintain the species at its maximum or desired limit and should preserve all that came into being until they had accomplished their mission. In oviparous creatures the destruction begins with the eggs, and to meet this these are often produced in prodigious numbers. The sturgeon is not an abundant fish, and yet the female spawns a hundred thousand ova. If all these could live one pair would stock all the rivers of America. The number of eggs spawned by a single eel sounds too fabulous to be believed, while in the lower invertebrate world the figures grow still more astounding, as for example that a tape-worm should possess a billion ova. In the vegetable kingdom we encounter the same class of facts. Burst a puff-ball and the air is filled with smoke, but each element of that cloud consists of a minute spore ready to germinate if by the rarest chance it shall find a suitable habitat. Some one has been to the trouble to determine the number of spores yielded by a plant of the common mould, and reached the incredible figure of three billions two hundred millions. But even among higher plants the same prodigality is seen. A large chestnut tree in June probably contains a ton of pollen, and many pines are equally laden with it, destined to be blown by the winds and floated hundreds of miles in the upper atmosphere. There are also many plants, like the orchid and the broomrape which bear myriads of minute seeds, not one in many thousand of which ever has an opportunity to germinate. These are only a few examples. Everywhere in nature the vital energy is squandered in the most prodigal manner. The amount expended on any one species would, if economized, carry on half the activity of the animal or vegetable world.

No one, so far as I am aware, has attempted to formulate the true law of biologic economics. Much has been said of the law of parsimony which is only a very subordinate one sometimes called into exercise, but of the great law of prodigality, which is universal, no adequate definition has as yet been offered. As the law of life in organic nature does not essentially differ from the law of force in inorganic nature, it may, for the sake of brevity, be designated as *the law of nature*, with which it is important to contrast the psychologic method, or *the law of mind*.

The complete law of nature is capable of being divided into two parts or members. We have seen that it is always directed toward some useful end and that from its very nature as a genetic process it is incapable of producing any necessarily useless thing. Its products must therefore all possess a possible or *potential* value. This part of the law may therefore be expressed by the formula that *every creation of organic nature has within it the possibility of success*. Thus far the biologic law is economical. But, as we have seen, only the minutest fraction of that which is created becomes an *actual* success. The second member of the definition must therefore be framed to express this truth. The principle that underlies it may be called *the necessity for certainty*, or *the paramount importance of certainty*. It might also be called *the multiplication of chances*. There seems to be no limit in nature to the degree of energy that may be put forth in the direction of securing certainty. The chances of survival will be multiplied a thousand times in order that certainty may be made a thousand times certain. The second member of the law therefore is that *in order to secure certainty the chances may be indefinitely multiplied*. The entire law may then be thus formulated: *All energy expended by organic nature results in potential utility, and actual utility is secured through the multiplication of efforts*.

The first member of this law may be characterized by the term *practical*. The second member may in like manner be called *prodigal*. Nature is therefore at once the most practical and the most prodigal of all economists: practical in that she never makes anything which has not the elements of utility: prodigal in that she spares no expense in accomplishing even the smallest results. Again, nature may be said to be engaged in creating every conceivable form. Everyone is familiar with the wonderful variety in the actual forms of vegetable and animal life. But these, innumerable as they are, only represent nature's successes. Intermediate between them there must be imagined an infinite number of failures — conceivable forms in the production of which the organic energy has expended itself in vain —a vastly greater expenditure than that required to create all that exists. Moreover, among the successful forms there are all degrees of success. There are the vigorous and robust forms rejoicing in a full measure of vitality and marching forward toward the possession of the earth. Then there are the weak and languishing forms which the former class is gradually crowding out of existence. Between these there are all the intermediate grades. But the successful are only temporarily so. Like human empires they have their rise and fall, and the path of natural history, like that of human history, is strewn with the remains of fallen dynasties and the ruins of extinct races.

If the expenditure of energy be designated the *cost*, then it may be said to be a characteristic of the law of nature to exaggerate the cost of any given result. The most economical way in which a river can flow is in a straight line from its source to its mouth. But even if one were to begin in this way it would, as a result of this principle, soon become crooked and then more and more crooked, until at length the actual distance traversed by every drop of water would be at least double that of a straight line. This physical law, which has been called the rhythm of motion, is carried into the organic world. The tendency is everywhere to exaggerate the irregularities of normal development. This goes on until it frequently results in abnormalities so great that they bring about their own extinction. Such were doubtless the strange dragons that, as paleontology tells us, inhabited the world during a certain geologic period; while the more recent mastodon and mammoth, and those wingless birds of the southern hemisphere, one of which, the moa, once known to man, is already extinct, furnish other illustrations. In the vegetable kingdom the coal flora is full of examples. Many living plants, either through parasitism, as the Rafflesia, which consists almost exclusively of a gigantic flower, or through extreme specialization, as in the orchids and yuccas, many of which are dependent upon a single species of insect which alone has organs adapted to fertilize their flowers, further exemplify this law. Such monstrosities inevitably perish with the slightest alteration in their material surroundings. The progress of organic development has thus been to a large extent the successive creation of types that have contained within themselves the elements of their own extinction. New ones, of course, have succeeded them adapted for the time being to their environment, but destined in turn to outgrow their conditions and perish from the same cause.

In this sketch of natural or biologic economics, its genetic character has thus far been chiefly left out of view, in virtue of which effects are always just equal to causes and never greater. The organic force is applied directly to the object to be transformed, and the forms to be created are molded into the required shape by an infinite number of minute impacts, the sum of which is represented by the transformation accomplished. No advantage is taken of any mechanical principle whereby the effect is made to exceed the energy expended. Natural selection has, indeed, evolved structures that embody to some extent such principles. Sharp teeth and claws like edged tools represent the inclined plane, and it may sometimes be carried so far as to imitate the screw, as in the appliances which some seeds possess for boring spirally into the earth. Again, there is no doubt that the manner in which muscles are attached often affords a true leverage and greatly increases the effectiveness of muscular action. But aside from these curious cases in which natural selection seems to imitate rational design, effect throughout organic and inorganic nature is exactly equal to cause, and the result produced by living beings is proportioned to the effort put forth. No animal, for example, is ever seen to make use of any external appliance, not even to the extent of wielding a weapon, such as a club or a stone, which is not a part of its own organic structure. The beaver, indeed, builds dams by felling trees, but its tools are its teeth and no further advantage is taken than that which results from their sharpness and the way the muscles are attached to the jaws. All the warfare of animals is waged with tooth and nail, with horn and hoof, with beak and spur and fang and sting—always with organic, never with mechanical weapons. And whatever work is done by animals is always done with tools that nature has provided through a long course of development, none of which takes advantage of any principle of physics further than as already stated.

Over against this method of nature, or biological economy, let us now set the method of rational man, or pschological economy. The most patent distinction which at once strikes the mind is that the latter is *teleological* instead of genetic and deals with final instead of efficient causes. This means that while organic forms are merely pushed into existence by the pelting of atoms from behind, and thus become fortuitous or literally chance products, human creations are conceived in advance by the rational and foreseeing mind, designed with skill for definite ends and wrought with the aid of a variety of mechanical principles by which the energy expended is out of all proportion to, and always less than the result accomplished. It is in rational man, therefore, that the first application of anything worthy of the name of economy is made. Nature has no economy. Only through foresight and design can anything be done economically. If nature produces nothing that may not possibly prove useful, man produces nothing that will not probably be useful. But nature creates many thousand actual failures to one actual success, while man, though he often fails through ignorance, is ever approaching a stage at which every effort shall succeed. His rivers (canals, millraces, irrigation trenches, etc.) are straight, or as nearly so as true economy of construction requires, and Professor Schiapparelli has based his belief that the planet Mars is inhabited by rational beings upon the supposed discovery of great water ways passing across its disk in right lines.

Nature's way of sowing seed is to leave it to the wind, the water, the birds and animals. The greater part falls in a mass close to the parent plant and is shaded out or crowded to death by its own abundance. Only the few seeds that chance to be transported by one agency or another to some favorable spot and have the further good fortune to be covered up can sprout. The most of these even never attain maturity, and only the most highly favored live to continue the race. To meet this enormous waste, correspondingly enormous quantities of seed are produced. Such is nature's economy. How different that of a rational being! He prepares the ground, clearing it of vegetable competitors, then he carefully plants the seeds at the proper intervals, so that they shall not choke one another, and after they have sprouted he keeps off their enemies, whether vegetable or animal, supplies water if needed, even supplies the lacking chemical constituents of the soil if he knows what they are, and thus secures as nearly as possible the vigorous growth and sure fruition of every seed planted. Such is the economy of mind.

A closer analysis shows that the fundamental distinction between the animal and the human method is that *the environment transforms the animal while man transforms the environment.* This proposition holds literally almost without exception from whatever standpoint it be contemplated. It is, indeed, the full expression of the fact above stated that the tools of animals are organic while those of man are mechanical. But if we contrast these two methods from our present standpoint, which is that of economics, we see at once the immense superiority of the human over the animal method. First consider the economy of time. It has taken much longer to develop any one of the organic appliances of animals, whether for war or industry, than is represented by the entire period during which man has possessed any arts, even the simplest. Look next at the matter of efficiency. Not one of the organic appliances has sufficed to enable the species possessing it to migrate far from the region to which it was originally adapted. Man, on the other hand, without acquiring any new organic adaptations, but by the invention of tools, by providing himself clothing and shelter, by artificial devices for capturing prey, and by other ways of transforming his environment, has placed himself in position to occupy the whole earth from the equator to the arctic circle, and to become the only animal that is not restricted in its habitat.

Every implement of human design is calculated to take advantage of some mechanical principle through which the muscular force necessary to be exerted is less for any given result accomplished than it would be without such implement. In most cases it is many times less, but in the great majority of cases no result could be produced at all without the implement. Machines are simply more effective tools, and it is through tools and machinery that the arts have been established. The utter helplessness of man without the arts is well illustrated by De Foe in Robinson Crusoe, and yet in order to enable him to survive at all, even in a tropical climate where nature's productions were exuberant, he must provide himself from the stores of the wrecked vessel with a considerable supply of tools and other artificial appliances. What was true of Robinson Crusoe thus circumstanced, is much more true of the great majority of mankind who inhabit what we call temperate climates, *i. e.* climates in which the temperature sometimes falls ten or twenty degrees below the freezing point. One winter without art would suffice to sweep the whole population north or south of the thirtieth parallel of latitude out of existence.

We are so much accustomed to the terms *labor* and *production* that we rarely stop to think what they really mean. Neither of these terms has any place in natural economics. All labor consists in an artificial transformation of man's environment. Nature produces nothing in the politico-economic sense of the word. Production consists in artificially altering the form of natural objects. The clothes we wear are chiefly derived from the sheep, the ox, the silkworm and a few other animals, the cotton plant, flax, hemp, and a few other plants; but between the latest stage at which nature leaves these and the final form in which they are ready for use, the steps are many and the labor great. The dwellings man inhabits once consisted chiefly of trees, clay, and beds of solid rock. These have been transformed by labor performed with tools and machinery into houses. The same is true of temples and of all the other buildings that now cover the surface of the earth wherever man is found. And so the entire cycle of human achievement might be gone through. All these transformations are accomplished through the arts.

The sum total of human arts constitutes man's material civilization, and it is this that chiefly distinguishes him from the rest of nature. But the arts are the exclusive product of mind. They are the means through which intelligence utilizes the materials and forces of nature. And as all economics rests primarily on production, it seems to follow that a science of economics must have a psychological basis. In fact the economics of mind and the economics of life are not merely different but the direct opposites of each other. The psychologic law strives to reverse the biologic law. The biologic law is that of the survival of structures best adapted to the environment. Those structures that yield most readily to changes in the environment persist. It has therefore been aptly called the "survival of the plastic." The environment never changes to conform to the structures but always the reverse, and the only organic progress possible is that which accrues through improvements in structure tending to enable organic beings to cope with sterner and ever harder conditions. In any and every case it is the environment that works the changes and the organism that undergoes them.

But the most important factor in the environment of any species is its organic environment. The hardest pressure that is brought to bear upon it comes from other living things in the midst of which it lives. Any slight advantage which one species may gain from a favorable change of structure causes it to multiply and expand, and unless strenuously resisted, ultimately to acquire a complete monopoly of all things that are needed for its support. Any other species that consumes the same elements must, unless equally vigorous, soon be crowded out. This is the true meaning of the survival of the fittest. It is essentially a process of *competition.* The economics of nature consists therefore essentially in the operation of the law of competition in its purest form. The prevailing idea, however, that it is the fittest possible that survive in this struggle is wholly false. The effect of competition is to prevent any form from attaining its maximum development, and to maintain a certain comparatively low level for all forms that succeed in surviving. This is made clear by the fact that wherever competition is wholly removed, as through the agency of man in the interest of any one form, that form immediately begins to make great strides and soon outstrips all those that depend upon competition. Such has been the case with all the cereals and fruit trees; it is the case with domestic cattle and sheep, with horses, dogs and all the forms of life that man has excepted from the biologic law and subjected to the law of mind, and both the agricultural and the pastoral stages of society rest upon the successful resistance which rational man has offered to the law of nature in these departments. So that we have now to add to the waste of competition its influence in preventing the really fittest from surviving.

Hard as it seems to be for modern philosophers to understand this, it was one of the first truths that dawned upon the incipient mind of man. Consciously or unconsciously, it was felt from the very outset that the mission of mind was to grapple with the law of competition and, as far as possible, to overcome and destroy it. This iron law of nature, as it may be called, was everywhere found to lie athwart the path of human progress, and the whole upward struggle of rational man, whether physically, socially, or morally, has been with this tyrant of nature, the law of competition. And in so far as he has progressed at all he has done so by gaining, little by little, the mastery in this struggle. In the physical world he has accomplished this through invention from which have resulted the arts. Every utensil of labor, every mechanical device, every object of design, and every artificial form that serves a human purpose, is a triumph of mind over the physical forces of nature in ceaseless and aimless competition. In the social world it is human institutions—religion, government, law, marriage, customs—that have been thought out and adopted to restrain the unbridled individualism that has always menaced society. And finally, the ethical code and the moral law are simply the means employed by reason, intelligence, and refined sensibility to suppress and crush out the animal nature of man.

One important fact has thus far been kept out of view for final treatment in this place. Man, it is true, is a rational being, but he is also still an animal. Notwithstanding the important conquests over nature that have been recounted, he is still very far from being master of the field. The difficulty is that mind itself was developed under the influence of the purely egoistic law. That extraordinary brain development which so exclusively characterizes man was acquired through the primary principle of advantage. Brain does not differ in this respect from horns or teeth or claws. In the great struggle which the human animal went through to gain his supremacy it was brain that finally enabled him to succeed, and under the biologic law of selection, where superior sagacity meant fitness to survive, the human brain was gradually built up, cell upon cell, until the fully developed hemispheres were literally laid over the primary ganglia and the cranial walls enlarged to receive them. The brain of man was thus originally an engine of competition. It was a mere servant of the will. It was only in virtue of its peculiar character by which it was capable of perceiving that the direct animal method was not the most successful one, even in the bare struggle for existence, that it so early began, in the interest of pure egoism, to antagonize that method and to adopt the opposite indirect method of design, foresight, calculation, and coöperation.

The law of mind, as it operates in society as an aid to competition and in the interest of the individual, is essentially immoral. It rests primarily on the principle of deception. It is an extension to other human beings of the method applied to the animal world by which the latter was subjected to man. This method was that of the ambush and the snare. Its ruling principle was cunning. Its object was to deceive, circumvent, ensnare, and capture. Low animal cunning was succeeded by more refined kinds of cunning. The most important of these go by the names business shrewdness, strategy, and diplomacy, none of which differ from ordinary cunning in anything but the degree of adroitness by which the victim is outwitted. In this way social life is completely honeycombed with deception.

The competition which we see in the social and industrial world —competition aided and modified by reason and intelligence—while it does not differ in either its principle or its purpose from the competition among animals and plants, differs considerably in its methods and in its effects. We see in it the same soulless struggle, the same intense egoism, the same tendency to exaggerate existing inequalities, the same sacrifice of the weaker to the stronger, and the same rage of the latter to possess and monopolize the earth. But, in addition to all this, the opposite principle is also in active operation. This is the law of mind making for a true economy of energy. This economy, however, is a purely individual economy and not a social or political economy. That is, it only benefits the individual, not society nor the state. The effort in each case is solely to benefit self. No account is taken of the benefit or injury of others. Usually the individual knows that it will injure others, and therefore, in order to prevent them from checkmating him, he resorts to one or other of the methods of deception above enumerated. But oftentimes no thought is given to its effect on society, the state, or other individuals.

It has been so strongly maintained that competition results in a real economy that it is worth while to consider this for a moment. The prevailing impression is that if permitted to operate freely it will necessarily keep down prices. There is no greater mistake made by economists. It tends to raise prices to their highest limit.

It does this by the waste it occasions, and the price must be made to cover this waste. In the retail trade of all kinds of commodities the waste is enormous. The number engaged in it is many times greater than is necessary. This is because society has put a stigma upon productive labor and trade is one of the principal ways of living by one's wits. Each seller must devise some means to induce buyers to buy of him instead of his rivals. One of the principal ways of doing this is that of making his goods known to those likely to want them. From pure inertia they will buy what is brought to them before they will go after it, or they will go to a place they know of rather than hunt another. Hence, every possible means is resorted to by each dealer to advertise his business. Newspaper advertising is the most familiar way, but it is by no means the only one. Costly as it is, it probably costs less than other modes. Among these, display takes a high rank—large French glass show windows illuminated at night even after the hours of closing, with gas or electric lights; add to this the necessity for locating on principal streets and paying high rentals. Posters and running agents, delivery wagons emblazoned with great letters, "opening" invitations sent to thousands, and a variety of other devices, all very expensive, are well known to all. For houses that can afford it all this is supplemented by the traveling salesman or drummer whose ubiquitous presence greets us on every railroad car and at every country hotel. Think of the enormous expense involved in this! There is a latent impression that it is in some way necessary. Yet such is not the case. All these varied modes of making known particular firms and particular goods are wholly unnecessary to society at large. Only so much is wanted and only so much will be bought. If it tends to cause more to be bought than is wanted it does harm. It is only a supposed necessity to each dealer to cause his goods to be bought instead of those of another dealer. But the consumer must pay for all this expensive rivalry. Pass by any first-class restaurant even at the customary hour for meals and you will see perhaps two or three persons eating in a hall that would comfortably seat fifty, in rear of which there will be ten to twenty waiters in dress coats and white gloves waiting for another guest to drop in, if perchance one should. No wonder that at such a place one must pay a dollar for a beefsteak that costs fifteen or twenty cents in the market. It is because the business is so greatly overdone, each competing to attract more than the others. It is the same with the drug business, the cigar business, the confectionery business, and a great number of other businesses.

All these are illustrations of competition under the law of mind. They are the devices of cunning persons to live without work or by some agreeable form of work, and society is regularly called upon to support them by paying in the added prices of all commodities all that the business will bear. This quality of business shrewdness, the modified form of animal cunning, resting primarily upon the principle of deception, is manifest in all forms of advertising. The chief object of an advertisement is to deceive the public and cause the belief that things are better or cheaper than they are. So well is this understood that there is no law to punish the most flagrant falsehood expressed in the form of an advertisement, and if the dupes and victims of this form of lying remonstrate, that great principle of the common law of England, *caveat emptor*, is laughingly brought forward as the all-sufficient answer.

These illustrations are drawn from one of the few departments in which permanent or at all prolonged competition is possible in society. In nearly all other departments the effect of intelligence is very different. It is mind alone that perceives that competition is wasteful, and therefore, in the interest of the very success that competition seeks, it proceeds to antagonize it and to substitute art, science, and coöperation. By the aid of these the success of those who use them is increased many hundred fold. Competition in society, therefore, tends to defeat itself. It cannot endure. It is at best only a transition stage. On the one hand, the competition between individuals soon takes the form of competition between machines. On the other hand it takes the form of competition between corporations. The former tendency is temporarily injurious but permanently beneficial. The latter is permanently injurious and becomes a serious menace to society. Still it is not an unmixed evil since it prevents the waste of competition. Even the retail industries above referred to are coming within this law. The small houses are being swallowed up by large ones and great universal stores are growing up in all large cities. They result in monopoly but they do not increase prices, and the quality of the goods sold is far more reliable.

The social phenomenon which conforms most nearly to the pattern set in the animal world, and which is most under the influence of the law of nature and least under that of the law of mind, is human labor. Wholly unskilled labor has rarely gone beyond the stage of pure competition. In the olden time skilled labor made a step forward in the formation of guilds, but the era of machinery swept these away. At the time when the founders of the present system of political economy were writing, labor of nearly every kind was almost exclusively competitive. It is only within a few decades that it has begun to fall under the influence of intelligence and to employ the simplest of all rational devices that of coöperation. Capital, on the other hand, being naturally in the hands of the most sagacious members of society, has always combined and coöperated and used all the other arts of overcoming competition. The chief difference between the employers and the employed, until recently, has been that the former have used the rational method, while the latter have used the natural method. But such is the power of the rational method and its superiority over the method of nature that competing labor stood no chance in the struggle with combining capital, and it was possible, to a great extent, to enforce the iron law of wages as formulated by Ricardo. And when, in recent times, labor at last began in a small way to call to its aid the psychologic economy of coöperation, the step was so unexpected and seemed so strange that it was looked upon as a crime against society, and many still so regard it. Indeed, all the laws of modern nations are framed on the assumption that capital naturally combines, while labor naturally competes, and attempts on the part of labor to combine against capital are usually suppressed by the armed force of the state, while capital is protected by the military and civil authority of the state against such assumed unlawful attempts. This enormous odds against which labor struggles in its efforts to adopt and apply the economics of mind will greatly retard the progress of industrial reform, which aims to place labor on an equal footing with capital in this respect.

The evil that results from the competition of corporations lies in the fact that, as in most competition among rational beings, it is only a brief transition stage to be quickly followed by further combination. Just as competition among individuals results in corporations, so competition between corporations results in combinations of corporations. A common form of these compound corporations is that which is known as a trust. This process of compound coöperation does not stop until all engaged in a given industry are embraced in a single combination and the whole product of that industry is controlled by it. This gives it absolute control over the price of the commodity produced, limited only by the maximum that can be charged without diminishing the profits. Thus, for example, all the petroleum produced by a country may fall under the control of a single trust, and in order to secure for the members of that trust the maximum return for the petroleum, its price will be placed at the highest figures that consumers of petroleum will pay rather than return to candles or resort to gas or electricity. It must not be put so high as to produce a great falling off in the consumption, otherwise there will be a diminution of profits, and this is all that regulates the price. There is no necessary relation between price and cost of production. The price may be twenty or it may be a hundred times the cost. The same is true of coal or iron or sugar or cotton, and even in the case of breadstuffs something analogous can occur through the device which is known as "cornering." All monopolies rest on the same principle and they are as common in the industries of transportation and exchange as in those of production. The railroad, telegraph, and express systems fully illustrate the law, as does also the mercantile business of every country, in all of which competition is short, heated, and fitful, and the result is always the same—the swallowing up of the small industries by the great ones in ever widening cycles.

And thus it comes about that nearly everywhere in human society the law of mind profoundly modifies the phenomena of industrial life, and produces an entirely different class of results from what would be produced by the operation of the unimpeded law of natural competition. Whether the competition be continued for a time or whether it be converted into a competition of corporations, or whether, finally, it resolve itself into complete monopoly, in any and all cases an enormous artificial difference will be produced between the cost of production and the price to the consumer, and the latter will be pushed up to the maximum limit attainable without affecting profits. In the first case this artificial difference is mostly wasted in aggressive competition, its only benefit to any one being that of doubling or trebling the number of persons who are enabled to live without productive labor. In the other cases and especially in the last, this difference goes to enrich the managers of trusts and to multiply millionaires.

All this is so widely different from what we see everywhere in nature below the level of man's rational faculty, that it requires the application of an entirely different set of principles from those which can be applied to irrational life. There competition is pure. It continues as long as the weaker can survive it, and when these at last go to the wall and the better adapted structures survive and triumph, it is the triumph of physical superiority, and the strong and the robust alone are left to replenish the earth. But when mind enters into the contest all genuine competition is crushed out, and while it is still, in a certain sense, the strong that succeed, it is a strength which comes from superior cunning, necessarily coupled with stunted moral qualities, intense egoism, and undeveloped sympathies, and always aided more or less by the mere accident of position. In no proper sense can it be said that this class is the fittest to survive in society. Considered from this point of view solely, it is evident that brains are a positive detriment to society, and if there were really no hope of discovering and applying a remedy it would doubtless have been better if they had never been developed. It is probably the contemplation of such a hopeless condition that has given rise to the pessimistic philosophy of India and modern Germany.

Free competition as it exists in nature would be preferable to the existing industrial state, and although it is not the boon that many suppose, it is still one of the great desiderata for which society should strive. How can it be secured? Herein lies a great social paradox. It is clear from all that has been said that this will never bring itself about. Competition is growing more and more feeble and ephemeral; combination is growing more and more powerful and permanent. And this is the result of the most complete *laissez faire* policy. The paradox therefore is that *free competition can only be secured through regulation.* The coöperative tendencies of the rule of mind which destroy competition can only be overcome by that higher form of coöperation which is able to stay the lower form and set the forces of nature free once more.

Let me indulge in a single illustration. Suppose a railroad to be built alongside of an existing canal. Negotiations will be at once begun to purchase the canal, not because it is wanted, but merely to remove it from competition. Such negotiations would be sure to succeed and leave the railroad master of the field. Competition would be removed, rates of transportation increased, and a valuable water way would be abandoned. But suppose society in its collective capacity, however constituted, seeing the situation and the danger, were to step in and itself purchase the canal, and to continue in spite of the railroad to conduct it in the interest of traffic; here would be a case in which the law of mind would be directed to maintaining instead of destroying competition.

Without enlarging further upon this subject, it may be said in defence of competition that a new and revised political economy will devote a large share of its energies to showing, not so much the glories of the competition that now goes on, as how society may conduct itself in order to secure whatever benefits competition can offer. These are considerable, but, as already remarked, they can only be secured through conscious and intelligent social control of those egoistic tendencies which either bring competition to a complete stop and substitute monopoly, or only allow it to go on in such extravagant ways as to be worse than monopoly. Under proper social restraint competition may undoubtedly be retained as an important economic factor. But it would then be divested of its fierce, crushing, and grinding character and reduced to the condition of friendly and healthful emulation which stimulates effort but does not work hardship.

Neither should the influence of the higher attributes of reason and intelligence be discouraged. They are the foundations of civilization and progress. But these, too, should be deprived of their fangs, and made to pursue the paths of peace, justice, and equity. This result, if it is ever attained at all, must be attained by a still higher application of this same law of mind—by the exercise of these higher attributes by society itself. Such a powerful weapon as reason is unsafe in the hands of one individual when wielded against another. It is still more dangerous in the hands of corporations, which proverbially have no souls. It is most baneful of all in the hands of those mighty compound corporations which seek to control the wealth of the world. It is only safe when employed by the social ego, emanating from the collective brain of society, and working for the common interest of the social organism.

But the object of this address was not to point out remedies for social evils. It was, as stated at the outset, to show that any system of economics which is to deal with rational man must rest upon a psychologic and not upon a biologic basis. It may seem strange, in the light of all that has been said, that there should be any need of calling attention to this truth. And so it would be were it not that, in full view of all these facts, the prevailing system of social economics and social philosophy, completely ignores them and treats the human animal only as an animal.

The old biological economics, culminating in the law of Malthus, has broken down at every point where it has had a fair trial. Its leading tenets have proved false in practice, and in the majority of cases the truth can only be reached by reversing the propositions. It may be profitable to enumerate a few of the economic truths which have been established by the industrial history of the last century and which consist for the most part in the simple negation of the dogmas of political economy as based on the law of nature, unaffected by the law of mind. I will express them in the briefest form without any attempt to elaborate, illustrate, or justify them, this having been done on former occasions[1] or by others, and it is

[1] See especially a paper entitled: "Some Social and Economic Paradoxes," in the American Anthropologist for April, 1889, Washington, Vol. II, p. 119.

not pretended that the propositions contain anything not already familiar to most economists.

1. Subsistence increases instead of diminishing with population (negation of the dogma of Malthus).

2. Competition usually has the effect to raise prices and rates.

3. Free competition is only possible under social regulation.

4. The evils of private monopoly can only be prevented by a resort to public monopoly.

5. In consequence of ignorance the individual cannot be depended upon to act according to his own interest, and the principle of *caveat emptor* works an unnecessary hardship.

6. The consumer cannot be depended upon to encourage the better producer, and competition results in deterioration.

7. The interest of the individual is rarely the same as that of the community.

8. Market values and social values are not identical, as *e. g.*, those of a forest.

9. In an increasing number of cases the hope of gain is not the best motive to industry.

10. Public service will secure better talent than private enterprise for the same outlay.

11. Private enterprise through aggressive competition and monopoly taxes the people far more heavily than does the state.

12. The prosperity of a community depends as much upon the mode of consumption of wealth as upon the quantity produced.

13. The social effects of taxation are more important than their fiscal effects.

14. The producer cannot always shift the burden of taxation upon the consumer, *e. g.*, under monopoly and aggressive competition.

15. True protection often reduces the price of the commodity protected, sometimes even in the importing country.

16. Capital, as equivalent to machinery, contributes more than labor to the product on of wealth.

17. Wages are drawn from products and not from capital, and the "wages-fund" is a myth.

18. Increase of wages is attended with increase of profits.

19. Prices fall as wages rise.

20. Diminished hours of labor bring increased production.

21. Reduction of the time worked enhances the wages received.

The enumeration might be continued to almost any length, but the above will suffice to show that the doctrines of physiocracy, *laissez faire* and Spencerian individualism, and the biologic economy in general, are not sustained, and that the facts which society presents are for the most part the reverse of those which were promised by them. The explanation is that the old political economy is true only of irrational animals and is altogether inapplicable to rational man. Darwin modestly confesses that he derived his original conception of natural selection from the reading of Malthus on population. But he did not perhaps himself perceive that in applying the law of Malthus to the animal world, he was introducing it into the only field in which it holds true. Yet such is the case, and for a reason that has already been given, viz., that the advent with man of the thinking, knowing, foreseeing, calculating, designing, inventing, and constructing faculty, which is wanting in lower creatures, repealed the biologic law or law of nature and enacted in its stead the psychologic law—the law of mind.

# PAPERS READ.

COMPETITION AND COMBINATION IN NATURE. By HENRY FARQUHAR, U. S. C. & G. Survey, Washington, D. C.

THE customary courtesy of our Association, shown in receiving without remark, and particularly without adverse criticism, the inaugural addresses of its Vice Presidents, is not any the worse respected by indulging an occasional transgression of the rule; and some reasons appear why one such transgression might not unprofitably be permitted to this Section at this meeting. In the first place, our presiding officer is himself too zealous for truth to seek protection from any blows and knocks which his pursuit of it may bring upon him, or to receive even the stoutest attack (if made in the spirit befitting lovers of truth) with anything but a welcome; in the second, the utmost light that can be thrown upon his theme, from a quarter however different, can only bring out more strongly the central truth of his address, the wastefulness of unlimited competition; in the third, that central truth is accompanied by another proposition, which, if it be really the grave error it appears, calls loudly for examination and serious modification.

That proposition is that the cruder competition spoken of, the unlimited competition of dissociated individuals, is the law of nature, while combination is the law exclusively of mind and of man. That concerted action, in which the interests of the individual as a competitor against his fellows are neglected for a more important interest of the individual and his fellows as an association, is something belonging to mankind as a species, distinct from and transcending nature in general, is a position whose maintenance is difficult to reconcile with even the most hasty consideration of the acts of ruminants feeding in herds, where, instead of a tumultuous crowding for the occupation of the best places, we see some individuals taking posts in which they can be of service in warning the whole herd of approaching danger—or of the wolves that prey upon them in coöperating packs. It is not to be rashly claimed that mind, mind as we ourselves exercise it, though doubtless without the high development of self consciousness that distinguishes our race, is absent from the conduct of ant and bee colonies; but surely their example is convincing evidence that the lesson of the economic superiority of concert over cut-throat individual competition is one that has been well taught and learned in realms of nature widely sundered from ours. The common working ant, deprived of the hard shell, the piercing eye, and the soaring wing, the lance in front and the lance behind, that are supplied in defence of kindred species, is a poor expression of nature's production as an individual competitor; and yet her life of toil, none for herself and all for her community, is as truly a result of nature's struggle for existence as any—for Nature's competition regards associations as well as individuals, and remorselessly suppresses the weapons of individual defence, whenever by saving and otherwise directing the vital energy they exact, she can evolve members of a social body which shall have a higher power of survival, as a body, than is possible to dissociated competitors. The ant reflects not on this and knows nothing of this, doubtless—we infer her lack of consciousness from her leaving no written records—but her disposition and power to subordinate individual to social ends is unsurpassed even in our own more highly conscious race.

If not with man as a self-conscious being, where in the course of evolution does an implicit recognition of the wastefulness of indiscriminate competition begin? Not even, I think, with the first appearance of gregarious animals. It is found at the point where parents first begin to care for their feeble offspring. The acts of the parent fish of certain species in building rude nests where their eggs may hatch undisturbed, or in carrying about with them their newborn offspring, are as truly transgressions of the law of individual competition as anything that human beings do. Their economic value to these fish as species, is vindicated in the diminished number of eggs that need to be laid, to keep their race from extinction, as compared with sturgeon and cod that never know their children. We may go back further yet—much further. It is an application of the same principle essentially unchanged when the organic cells, which are in the lowest organisms independent beings, first unite in filaments to form an aggregate of the second order, each cell giving up a part of the strength with which it could carry on a rivalry with its comrades, for a power of coöperation which makes the aggregate far better able to sustain itself than as many separate rival cells could ever be. In few words, we find in the truth that combination furnishes greater strength in competition than universal competition itself can furnish—this principle supposed a new development when the mind of the human species first arose from its elements—nothing more than is universal throughout organic nature; and its characterization as something in conflict or contrast with nature's methods, something transcending the whole scope and power of nature, is suggestive only of incomplete realization of what the scope and power of nature is. True it is that nature is coarse, and cruel, and clumsy, and prodigal, in a partial view of her; but in a wider view she includes the very excellences that have been vaunted as transcending her.

It is significant that in all the instances to which I have asked your attention, the effect—we may even say the object—of replacing competition by combination is more efficient competition. The vice-presidential address made allusion to this feature. I remember being struck, as a boy, with the fact that so many of the games I learned to play—rivalry being recognized as the essential principle of a game—were so arranged as to make this rivalry one between two parties, the individuals of each party being comrades instead of rivals to one another. The reason is clear enough to me now: an increased zest is given to that rivalry, on which the game is based, by the sympathy of others who enter into it as we do; and an increased power of overcoming opposition is given by division of the work among coöperating participants. In the theater of severest competition, a battle field, there can be but two combatants; "he that is not with me is against me." So it is in the contest between black rats and Norway rats, or between colonies of kindred ants. The elimination of competition, in fact, is much like that of "motion," or energy, in the general system of evolution. It must be present in some form, is an absolute indispensable, and yet progress is only attained by driving it back. "Evolution is an integration of matter and concomitant dissipation of" energy, Spencer tells us, showing at the same time that the necessarily retained energy "undergoes a parallel transformation" with the matter which concentrates as it dissipates.

Spencer's psychological system is based upon an identification of mind with life, each being in its own way a "continuous adjustment of internal to external relations," and our vice president has reminded us that the same doctrine had been taught in France before Spencer's day. I was greatly impressed, in my early study of the evidences for evolution according to Mr. Darwin, by finding so close a correspondence between what were proofs of natural selection for him, and what had been set down as proofs of conscious design by older philosophers. The coincidence was too close to be passed over as fortuitous; and it led me to the conclusion that design and natural selection were, after all, but two sides of the same thing—that when we consciously adapt means to ends, we do this by approval of some and rejection of others, the rival means being subjected to a struggle for life, quite like that which Darwin has taught us to see in the organic world. When the adaptation has become habitual, this struggle of rival means, with survival of the few and obliteration of the many, is symbolic rather than actual; though Edison had to try and reject dozens or scores of devices before he hit upon the filament of bamboo charcoal that gave the best incandescent electric light, and though the first inventor of the telephone transmitter had to make almost as many abortive attempts before he found the form that did the best work, later workers in the same field, finding the results of their labor recorded on paper or in memory, have been able to make far shorter work of adapting means to ends. Design, in all cases but the very first, is a short and easy process when once the way has been marked out. But not in that regard is natural evolution different. The way from fish to vertebrate, when first traced out by nature, needed countless weary ages of geologic time, countless bloody battlefields and scenes of dire tragedy, countless abortive pushes in wrong directions, before the final goal could be reached; but, once traced, it is habitually, easily, smoothly, unerringly, retraced in the few months of embryonic growth, where the unformed vertebrate must pass first through the fish and afterward through the reptile type before it can take the higher rank to which it is destined. Here we find the same effect of recorded experience, become habit, to which we are accustomed in human contrivance. The old proofs of design are the new proofs of selection therefore, because design is selection. Nothing is more characteristic of the higher intelligence than this power of adjusting means to ends, and yet it is but the conscious following of a course followed by nature unconsciously. It was Froebel, the renowned German educator, who sought to make of man the voluntary, as nature is the involuntary, mirror of God's will; so that the power of being this, even though it be the highest of human attributes, is not an attribute that isolates us from nature. Man is, I have long believed, the most completely natural of nature's works—for in none other do her powers and modes of evolution find such adequate expression.

If the economy of man, then, shows us nothing radically divergent from the economy of nature, we are justified in distrusting all inferences from the hypothesis that the divergence exists. To sound this note of caution is the object of the present paper. I seek not to defend any writer on political economy. If any have taught that universal competition, carried to its utmost limit, is the foundation of wealth, let them be condemned; but condemned for overlooking the real character of Nature's economy, and not for upholding it. Such writers, whoever they may be, have failed to see not only the significance of any association of men for a common end, but the utility of combination in social animals. If any have taught that associations of men are suitable and laudable for certain purposes, but obnoxious to sound economy for all other purposes, let them fall under the same ban but not because combination is the law of man and unknown to nature outside him. Economic science is not condemned in their condemnation; nor, much as it yet lacks of the perfect development possible to it, is the mass of experience on which its principles are founded, to be set aside by a few hasty inductions. It should be remembered that, notwithstanding the admitted truth that induction is the foundation of economics, inductive proof is only valid where all causes but one have been scrupulously excluded or allowed for: so that, pending the application of this principle to the propositions which concluded our Vice President's address, we are entitled to regard them, not as established, but only as more or less probable.

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THE STANDARD OF DEFERRED PAYMENTS. By EDWARD A. ROSS, Associate Professor of Political Economy and Finance at Cornell Univerity.

[ABSTRACT.]

THE paper seeks to ascertain what constitutes justice between debtor and creditor and what monetary standard will secure justice.

The *raison d'etre* of all bimetallists, whether national or international, is the need of more money in order to prevent injustice to the debtor class. If no injustice exists, vain are all attempts to show the practicability or the efficiency of bimetallism. The argument showing the injury the debtor class receive from falling prices is, then, the primary, fundamental argument on which all other bimetallist reasoning is built. Break down this and the whole theory falls to the ground. The argument takes its start from the fact that time contracts calling for future sums are based upon the present value or purchasing power of the money unit. Justice requires that the terms of the contract remain unaltered; that is, that the purchasing power of the unit be constant. If, in fact, the unit appreciates, the debtor is wronged. But appreciation is simply fall in prices regarded from a certain view-point. Hence fall in prices means loss to the debtor. Now a general fall in prices, averaging from one and a half to two per cent. annually, has occurred during the last twenty years and even now continues. This means a stupendous robbery of the debtor class. A monetary system which permits such a fall is self-condemned as dishonest and iniquitous.

The mono-metallists meet this argument by pointing out that the fall in prices is natural, and results from the abundance of commodities. Recently the output of commodities has enormously increased owing to great improvements in production. New inventions and new sources of supply have cheapened almost all articles. All along the line the economies resulting from better industrial leadership and more thorough organization have aided in lessening cost. This means that the relation between labor and product has changed. To this is due the fact that, while commodities have fallen in price, wages have shown a slight upward tendency.

Reverting to the case of the debtor it appears that the sum he repays to his creditor, albeit it represents more commodities than the original sum, represents no more labor. He may restore double the quantity of products, but, owing to increase in industrial efficiency, they represent only the same quantity of labor. And as, according to the classical economists, all fair exchange is the exchange of equal service, or of the products of equal quantities of labor, we may conclude that the gold standard brings no hardship to the debtor.

The opposing arguments just reviewed involve two controversies:

(1). As to the ultimate standard of value.

(2). As to the destination of the benefits of industrial progress.

In regard to (1) the bimetallist maintains that the debtor should restore only the quantity of *commodities* represented by the loan, while the monometallist insists that he should return the quantity of *labor* represented by the loan. As both agree that the debtor should restore equal value we find here the issue fairly joined between the two great opposing doctrines of value—the theory of *labor value* and the theory of *use value*. The one derives value from production; the other from consumption. The one looks to cost; the other to utility. The one regards sacrifices; the other satisfactions.

It is not difficult to show that the labor value theory rests upon a faulty analysis. A good possesses value or importance not on account of its past, but on account of its future; not because it embodies past sacrifices, but because it promises future satisfactions. The labor value theory of Ricardo rests upon observation of competitive industries of constant returns. But the growing importance of monopolized goods and of industries of diminishing returns has compelled a wider study, resulting in the discovery that value is a particular utility, viz., *marginal utility*. This idea, thrown out by Jevons and developed by the Austrians, has changed the face of economic theory within a few years. By revamping the obsolete labor-value doctrine the monometallists have shown themselves the Bourbons of Political Economy.

In regard to (2) the monometallist contends that the benefits of industrial progress should belong to the creditor. The bimetallist holds that they should remain with the debtor.

If it be urged in behalf of the creditor that justice demands equal sacrifices regardless of satisfactions, it can be replied that the argument involves the labor value fallacy and is therefore worthless. Nor can it be justly urged that the creditor deserves the benefits of the cheapening of production because so much improvement comes by way of bettering fixed capital. The creditor, as such, supplied only pure capital; its investment in better and ever better machinery is not due to him.

On the other hand, it may be argued on behalf of the debtor's claim to the benefits of industrial progress, that even on the labor value theory he cannot justly be called upon to restore an equal quantity of labor to his creditor, seeing that his labor is of superior efficiency and hence not of the same quality. But, again, it may be urged that in any case the debtor is not bound to meet the requirements of the labor value standard. For the transaction of debtor and creditor is a case of exchange of goods produced under different industrial conditions. And in such cases, as is evidenced by the course of trade between nations at different economic stages, values are ultimately determined not by cost but by utility. This would seem to leave all the benefits of industrial progress in the hands of the debtor.

But another course of reasoning shows ground for *sharing* the benefits. The debtor is bound to return to his creditor utility equal to that he received. But will this be done by restoring an equal quantity of goods? Only in case the objective utility of the goods remains the same. In fact the objective utilities of most goods are constant for a long period. But the utilities of those goods that the possessor uses in procuring social distinction, esteem, influence, etc., have a very fluctuating utility. And, in the case of a general rise in the scale of living owing to the abundance due to industrial progress, the objective utility of a good devoted to procuring social satisfactions would tend to lessen. Solely on this ground can we justify any participation of the creditor in the benefits arising from industrial progress.

Applying these results to the problem of the standard of deferred payments we conclude that the money supply should be so plentiful as to permit only that very slight fall in the prices of consumption goods which is required to compensate the creditor for the diminishing utility of goods expended in procuring social satisfactions.

### ECONOMIC CONDITIONS ANTAGONISTIC TO A CONSERVATIVE FOREST POLICY.

By B. E. FERNOW, U. S. Dept. Agric., Washington, D. C.

[ABSTRACT.]

THE forestry problem exists not only in the United States but among all civilized nations, being only more or less near solution in the different countries. It arises from the fact, that forest areas fulfil two distinct and independent functions, namely, that of a valuable resource of useful material and that of an important condition of the earth's surface. The problem summarily stated is, how to develop and utilize the resource without destroying or impairing the condition as far as this is of beneficial influence on other cultural conditions.

The conciliation of these two interests, namely, that which attaches to forest areas as objects of industrial activity and that which they claim as needful regulators and preservers of climatic, hydrologic and soil conditions, is the main problem. Minor problems are the management of the resource with a view to continuity and greatest usefulness and the extension of the resource as well as the creation of forest conditions, where they may be beneficial in improving climatic, water and soil conditions.

The solution of the problem lies in the application of forestry, that is, a treatment of the forest areas, based upon scientific and rational principles, upon a knowledge of physical, physiological and economic facts.

The physical facts are those which relate to the interdependence between vegetation and meteorological, soil and water conditions; they predicate the necessity of keeping certain areas under forest cover and determine or ought to determine the forest policy of the statesman and the legislator.

The physiological facts are those which relate to the development of forest growth and form the basis for the technical manipulations determining the forest management by the forester.

The economic facts are those which have reference to the conduct of forestry as a business, the relations which this business has to other classes of business, the financial aspects, determining the actions of the forest owner, and which, if we permit the State as we in reality do, to interfere with industrial activity, become also matters of concern for the statesman and legislator.

Granting that the facts regarding the relation of forest areas to other cultural conditions are so well established that the desirability of maintaining favorable forest conditions in certain given localities is beyond question and that a conservative forest policy becomes a matter of public concern we propose to inquire what difficulties from economic considerations there are in the way of inducing private forest owners from inaugurating such conservative forest management as will satisfy the needs of favorable forest conditions. Such management would require that the forest owner cut his timber in such a manner as to reproduce the forest or else replant what he has cut and that he take care to protect the forest growth against destructive agencies like fire, cattle, insects, or other, in fact that he manage his property with a view to continuity, that he apply a rational system of forest management.

There are certain economic peculiarities pertaining to forest growth and forest management and there are certain general economic conditions prevailing at the present time in the United States which must be understood, before the question as to the likelihood of a rational forest management being adopted by forest owners can be discussed.

Forestry as an industry has in view the production of a wood crop from the soil. This crop differs from other agricultural crops in that it may be raised on soil agriculturally useless; that it can be reproduced naturally by the mere method of harvesting; that it is not an annual crop which is harvested, but an accumulation of annual crops which alone is useful. It takes, therefore, a number of years before a useful crop can be cut; nor is the time when the crop may be harvested determined by any definite natural period like the ripening of fruit or by any other distinct sign of maturity. Two important conditions result from this, namely, in order to carry on a continuous forestry business, a large stock of accumulated wood growth or growing product must be maintained and the time at which the crop may be cut is at the discretion of the owner and not predicated by a definite time of maturity as in fruit crops.

While then in agriculture outside of the cost of soil and implements but a small amount of capital is invested, in a forest management, a considerable amount of capital is tied up in the accumulated stock, and the amount so tied up increases with the length of time the crop is allowed to accumulate, *i. e.*, with the time of rotation, without a proportionate increase in annual mass production. For example's sake, a coppice growth, which would produce firewood and small dimensions only, may be cut over every twenty-five years, setting the amount of wood at the end of the rotation as twenty cords per acre, an area of 1,000 acres managed for continuous annual revenue would require a stock of $\frac{1{,}000 \times 20}{2} = 10{,}000$ cords standing of which annually $\frac{1{,}000 \times 20}{25} = 800$ cords, the annual increase over the whole area may be cut. If instead of the coppice we allow a timber forest to grow with a rotation of eighty years, the stock on the 1,000 acres, if the wood growth per acre at the end of the rotation amounted to fifty cords a good average figure, the stock to be maintained would be $\frac{1{,}000 \times 50}{2} = 25{,}000$ cords of which in an ideal forest management annually $\frac{1{,}000 \times 50}{80} = 925$ cords only can be cut; to be sure the wood being of a more useful quality and higher priced. That is to say not only a larger reserve but a proportionately smaller cut is predicated by a longer, *i. e.*, more conservative rotation.

This stock or, as it is called, normal reserve, is a most important feature of forestry, by which it differs from all other enterprises and which gives rise to certain peculiarities of this kind of property especially with reference to insurance, credit and renting.

The reserve is exposed to various dangers, such as fires, insect pests, frosts, windstorms, depredation. The effect of these dangers is a different one according to the age of the growth and also according to the nature of the damage. Some of these detrimental agencies may destroy (like fire) the entire reserve, others impair only the regular progress of management making premature utilization necessary (windfalls) or deteriorate the quality of the reserve (insect ravages). Altogether the hazard and risk in maintaining the normal reserve is considerable and increases in proportion to the length of rotation. Hence there is a natural tendency on the part of the owner to reduce the reserve, *i. e.*, to depart from the principles of continuous conservative forest management.

In the carrying on of farming business, the credit system plays an important part; the value upon which loans are made being represented by the soil, little apt to deteriorate, as well as the crop which, being of one year's season only, is not exposed to many dangers. In the forest, the reserves and not the soil form the basis of value for the credit, and more dangers from natural as well as human agencies arise to this factor of valuation, hence forest property is an investment, which gives but undesirable basis for credit systems and hence again private owners are apt to dispose of it or take off the value accumulated in the reserve at the earliest opportunity without regard to a rational management. From the same reason forest growth is not a fit property for renting because the renter can hardly be controlled in maintaining the proper reserve. It is always difficult to determine what should be considered legitimate crop; what, reserve. Furthermore, the reserve is open to depredations through the whole year and from year to year, hence a considerable expense for protection is necessitated.

"If," Roscher says, "the sale of farms is carried on, not for the purpose of managing them, but to re-sell and pocket the difference, agriculture must languish. But with forest property such abuse is much more dangerous and also much more to be anticipated, on account of the nature of forest management, so that continuity of ownership in forests is of the greatest advantage." That means forest property is not a satisfactory object for speculation, if conservative management is to be maintained.

Another reason why forest management does not offer a field for speculation is, that technical and economic changes are slow to respond in results, so that favorable junctures in market conditions cannot be readily utilized. It takes many years until a change in methods or manipulation becomes apparent in results: the forest owner must, therefore, be possessed not only with considerable technical knowledge, but with a large amount of patience and strong character not to be induced to throw away the later greater advantages for present small gains and to be willing to abide results of his technical manipulations.

The reserve is capital difficult to control and easily reduced, and while such a reduction offers a temporary increase in the dividend, the excess over the proper amount must be saved in the future dividends, to which the owner is not readily disposed and the result is disastrous to a regulated forest management. Forest management then involves the curtailment of present revenue for the sake of a continued greater revenue in the future. It requires, therefore, continuity and stability to a greater extent even than agriculture.

The length of time which it takes for a crop to grow ready for the axe necessitates a much larger area to be under one management, than in agriculture, in order to make a regulated management altogether practicable and to occupy the manager fully or to yield to the owner a sufficient and continuous income. To be sure, the ownership and management of small tracts of forest land especially in connection with farm lands is not excluded, but experience has shown that sooner or later the small forest owner is forced to abandon a regular management, finding himself at a disadvantage as against the holders of large areas in the economical working of a system of management. Especially will this be the case, where not only small local demands are to be served, but a large market is to be supplied. This will readily be admitted when we consider the factor of transportation in the business of marketing the crop.

While it would pay to build roads and railroads where a constant or continued supply of sufficient freight is assured, as in the case of a large area of well managed forests, such constructions would not be practicable or profitable where small and scattered holdings without a uniform and systematic management are only to be developed.

The question of transportation becomes more and more important, as with the agricultural development near the markets, the forest is more and more relegated to the back country. Transportation which often at the place of production itself in the forest has to battle with peculiar difficulties, becomes proportionately a greater and greater charge so that the cheaper grades of wood, like firewood, cannot any more be profitably shipped.

Accessibility to market, easy, cheap and permanent means of transportation are conditions without which profitable forest management cannot be carried on; the bulkiness of the material making these conditions more necessary than in most other enterprises.

One of the most difficult matters is to determine the profitableness of any business in the abstract, since profitableness depends upon many varying conditions. There are, however, some special additional difficulties connected with the forestry business, which result from the long time of production. Until the harvest, the premises of calculation may have changed considerably. Whether the prices to be obtained eighty or one hundred years hence will warrant an expenditure to-day, who can tell? Whether a manipulation like a thinning for instance, will repay itself in increased financial results is most difficult to determine and altogether finance calculations in forest management are necessarily much more complex and based much more on anticipatory premises, than in other enterprises.

Especially difficult also is the adjustment of supply and demand. Not only are forestry statistics difficult to obtain, but even if obtained and if a shortage should appear, the adjustment must necessarily be very slow.

All these difficulties are apt to breed an uneconomical spirit among forest owners and are antagonistic to a conservative forest policy. Especially where the maintenance of forest conditions from protective considerations is necessary, the attempt to get the highest profit, which is the only incentive for private enterprise, is not always in consonance with what a conservative management may demand. It is easy to deforest, to devastate, to destroy, but most difficult to replant and restore; too often the forest is endangered and the interest of society hazarded.

In the United States in addition to these detracting peculiarities of the forestry business, which exist everywhere, there are other difficulties arising from general economic conditions antagonistic to a ready adoption of a conservative forest management by private forest owners.

There are three classes of forest owners: the farmers, who have wood lots connected with their farms, the speculators, among which I include all those who hold forest property temporarily for the purpose of selling it to obtain the unearned increment from the third class, namely those who develop and utilize the forest resource, lumbermen and manufacturers.

The first class should be considered a safe and conservative one and holding forest property to the extent of from thirty-five to forty per cent, we might feel safe regarding this part of the country's forest area.

No doubt, whatever attempt at rational forest management exists in the United States may be found among the farmers. It is probable, however, that a large part of their forest property is held only for speculative purposes, and besides the opportunity of paying off indebtedness by sacrificing the wood lot is not unfrequently embraced and it is done not in a conservative manner from lack of conception of the true value of this part of the farm.

The speculators are harmless as far as forest conservancy goes perhaps even an advantage in keeping their holdings from utilization until a change of market conditions might make a more rational exploitation of the forest practicable. It is then the lumbermen or those who make it a business to exploit the forest resources, to whom we must look for a forest policy. Here again we must distinguish between those who supply the raw material to others, engaged only in logging and those who supply themselves, their mills, manufactures, charcoal kilns, etc.

The latter might be expected to have conservative tendencies and to some extent they do exhibit them in the care of their forest property; but their foresight usually does not reach beyond many years, certainly not to the length of a rotation and as to application of real forest management, I have never heard of any attempt as yet.

Altogether, the general speculative spirit prevailing in all classes of society and business breeds instability and is detrimental to anything that depends on decades or centuries for results, as does a forest growth.

Those engaged in logging business only are the ones that have the least regard for the future, the most wasteful and reckless methods of exploitation are theirs; after them fire or the deluge!

To induce any forest owner to adopt rational and conservative forest management, we should have to show him that it is directly profitable—profit, we must never forget, is the only incentive for private enterprise. Now from the foregoing statements it will have appeared that this is difficult, almost impossible to do in a general way, and it is questionable in my mind, whether in many, perhaps in most localities, forest management for the present can be shown to be profitable. The wanton waste and destruction, to be sure, is not profitable — certainly not to the nation at large—but forest management means more than abstaining from wantonness. It is not only a negative but a positive business. It means application of knowledge, it means expenditure for a manager and other requisites of an organized management, expenditures for protection, curtailment of present profits for the sake of a continued revenue, expenditure in the present for the sake of gain in the future.

There are two main objections on the part of forest owners to such expenditures: the first is, the hazard to which their property is exposed under our poorly administered laws, especially against damage from fire; the second is, that as long as forest supplies from virgin growth compete in the market, with only the cost of harvesting and transportation placed upon them, there seems no money in the business, if there is an additional cost of production in the shape of expenditure for management to be placed upon it.

Whether or not this argument is correct in the long run, when we have in view continuity of the business, it will be difficult to show its incorrectness.

The lumberman, accustomed to carry on his business like the butcher, slaughtering his herd and finding his profit in the difference of the price he paid for the cattle and the price he got for the meat, is not readily to turn into a forester, who like the breeder finds his profit in the sale of the young increase, treating his herd as the capital.

Additional difficulty lies in the absence of educated foresters, competent to advise and carry on a management under such difficult economic conditions. So that, even if the forest owner were willing to try the experiment he would not be able to secure the manager.

The result of all these considerations is, that profitable exploitation of our forest resource and forest conservation or conservative forest management are at present more or less incompatible. At best any scheme of introducing forest management would be an experiment, which few private forest owners would be willing to risk. Hence, where the preservation of forest conditions is of importance to the community, the community alone will be able to insure their preservation; for the community alone can afford to forego the immediate profits arising from conservative exploitation, for the sake of an indirect object, that of favorable soil and water conditions. The community or rather the government, State or Federal, can alone afford to establish such an experiment, and after it has shown the methods to be employed, after it has offered the opportunity for the education in theory and practice of forest managers, there will be more inclination for private enterprise to follow suit.

The United States Government owns some fifty or sixty million acres of forest land under conditions where forest preservation is a necessity, where inducement to conservative forest management on the part of individual owners is even less than in our eastern states, where dire calamities are bound to follow a policy of neglect and forest destruction.

The policy for the government is clearly to reserve these areas and place them under a circumspect management by which, while the needs for timber of a growing population are subserved, forest conditions are kept in favorable condition.

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SOME STATISTICS OF THE SALVATION ARMY. By CHAS. W. SMILEY, Washington, D. C.

[ABSTRACT.]

THE figures concerning the general work of the organization have been obtained from General Booth and are for the year 1891, with some comparison for 1892.

Societies in 1891, 4,292; in 1892, 5,283.

Officers in 1891, 10,452; in 1892, 11,113.

Local officers who follow their own business by day and give spare time to the cause, 18,744; bandsmen, 12,744; sergeants, 5,500.

There are eighty-six training colleges with 1,016 cadets in training for officers. Thirty-four different languages are taught. There are twenty-five homes of rest. They publish thirty-two periodicals which circulate forty-seven million copies. They employ 130 persons in rescue work and have received 1,484 girls into their rescue homes. In their labor bureaus they registered 16,493 people and found work for 4,696. They received into their homes 334 discharged criminals and took 1,459 persons into their factories.

I have gathered the following facts regarding the "Social Wing" in London which supplies food and shelter. The quantities given are quite liberal and the quality is such as poor people should feel quite satisfied with.

Comfortable shelter with mattress and covering, four cents per night. This includes the use of lavatories with plenty of hot and cold water. During the first six months of 1892, they sheltered 370,253 poor people and supplied 1,359,316 meals at prices ranging from one-half cent to eight cents each. Some prices of meals are as follows: Soup enough for a child, one-half cent; for an adult, one cent. Soup with bread for a child, one cent; for an adult, two cents. Coffee for a child, one-half cent; for an adult, one cent. Bread and jam, one-half cent per slice. Cabbage, one cent. Potato, one cent. Beans, one cent. Boiled jam pudding, one cent. Boiled plum pudding, two cents. Rice pudding, one cent. Baked plum pudding, one cent. Baked jam roll, one cent. Fruit pudding, two cents. Beef and potato, four cents. Meat pudding and potato, six cents. Corned mutton and potato, four cents. Tea or cocoa, one cent per cup; two cents per mug. Soup to be carried away in bulk, two cents per quart. Of course, there are no napkins nor table cloths, but the tables, floors, and chairs are kept quite clean. The food is passably well cooked and is nutritious. The denizens of the slums would be elevated by contact with such influences.

*Manchester, England, July 27*, 1892.

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OUTLINE OF STATUTE TO PROMOTE WORKS OF PHILANTHROPY, INSTRUCTION, SCIENTIFIC RESEARCH, EMBELLISHMENT AND MEMORIAL ARTS WITHIN STATES, AND ALSO TO REGULATE THE SUCCESSION OF ESTATES OF DECEASED PERSONS AND TO TAX INHERITANCES THEREOF IN CERTAIN CASES. By R. T. COLBURN, Elizabeth, N. J.

[ABSTRACT.]

THIS paper is supplementary to one read by the author, before Section I at last year's session, advocating a Reform in the "Code of Inheritance," and the formation of a Department of Beneficence as a separate and benign function of state government. The agency recommended is that of a Board, or Council, of Amelioration, composed of citizens qualified by training and character for the duties. This Board would offer, ready to hand to the benevolently inclined, an organization and experience for the receipt of bequests superior to any trust which the wisest testator can devise. In addition it is proposed to levy upon large estates only, a tax, graduated according to the needs and degree of kindred, the proceeds of which will be applied by the Council to works of compassion, amelioration, recreation, research in the neglected fields of knowledge and to experiments in sociology upon a comprehensive and systematic plan.

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THE LABOR PROBLEM IN AMERICA. By ROBERT H. CRAFTS, Minneapolis Minn.

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MOVEMENT OF DUTIES AND PRICES IN THE UNITED STATES SINCE 1889. By HENRY FARQUHAR, U. S. C. and G. Survey, Washington, D. C.

# EXECUTIVE PROCEEDINGS.

## REPORT OF THE GENERAL SECRETARY.

THE forty-first meeting of the AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE was called to order on Wednesday, Aug 17, 1892, at 10.20 A.M. in the Chapel of the University of Rochester, Rochester, N. Y., by the retiring President, Prof. ALBERT B. PRESCOTT of Ann Arbor, Mich. Professor PRESCOTT said:—

The forty-first meeting of the American Association for the Advancement of Science is now open. The one word that I have to say is with regard to the previous meeting held at Washington. I now wish to introduce to you a man chosen at that meeting; a grand and glorious man, worthy of the office of president. I introduce to you JOSEPH LECONTE, the eminent geologist, the president of this body.

PRESIDENT LECONTE arose and said: Ladies and Gentlemen, I thank you from the bottom of my heart for this great honor which you have conferred upon me.

There are, my friends, three divisions of research which are worthy the efforts of human intellect. They are religion, fine art, science,—three sisters destined to coöperate in elevating the nature of man.

What can be grander than to be reckoned as a student of these three. The pursuits of scientific investigation are without doubt the greatest honor of the time. And I, as the president of this body, personally have been honored beyond my due in receiving this office. I have met with the body since 1851. You remember the great names that were registered at those meetings. There we saw Dana, Guyot, Agassiz and many illustrious men.

But let us not cling to the past and honor it solely. We must not underestimate the present. The golden age is ahead of us and not behind us.

Now, the last time I met with you was in 1860. Then came the war and my removal to California. I lost the stimulating effects of the young men. We are apt to think that we teach and educate the young, my friends, but they react on us and we educate only in proportion as we are educated.

Last of all, let me say, I shall require your constant forbearance. The qualities that I possess do not fit me to preside at meetings of bodies. I have lived in the world of thought and not in the world of men. If this were a political meeting, in which there was to be any strife, I should have resigned immediately, but a body of scientific men are a law unto themselves. Nevertheless, I shall rely upon your assistance and correction. Again I thank you.

The Rev. C. B. GARDNER then led the invocation.

Dr. E. M. MOORE, President of the Local Committee, then delivered the following address of welcome:—

It becomes my very pleasant duty to welcome you to our city. Such welcomes are your annual experience. But I desire to say nowhere has it been more heartfelt than that I extend to you as the representative of our rural City of Flowers. As you may follow the inclinations of curiosity in wandering over the avenues of its homes, you will be assured that the realizations of the *rus in urbe* is largely attained. Large enough to obtain the luxuries of metropolitan life, it is not hemmed in by any difficulties of expansion, and the growth in all directions is a perpetual guard against the severe competition for a resting of the busy worker. Thus it became early a city of homes. A few years since, under an inducement of a business nature, a private census (if I may use the phrase) was accurately made, developing the extraordinary fact that in consequence of the law allowing holdings of real estate before the expiration of the allotted time necessary to obtain the naturalization of the immigrant, there were found to be more landholders than voters. This, if not absolutely exceptional, was certainly a rare condition. I do not intend to indulge in a strain of municipal chauvinism, but follow precedents of introduction to the city you have honored by your visit. But while we highly prize the green that surrounds and the shrubs that adorn our humble abodes as well as the grand residences of the wealthy with winter as well as the summer garden, we recognize the advantage of concentration in the successful prosecution of business.

A few years since one of our citizens, a veritable genius in financial affairs, conceived the idea of building a structure copied from the fire-proof creations of brick, stone and iron, which seemed to be possible only to the resources of the government. It was certainly one of the first of its kind to be made with the expectation of financial success. The whole community was conservative, nothing but disaster was to be expected. Mr. Powers, however, was wiser than all others. The success was complete, and capitalists have followed his example to such an extent as to demonstrate the fact that no building can be rented near the centre of the town with any hope of successful competition, unless it be of the same pattern. Already has this example been admirably copied. The future of the structures in the centre of the city must be of a kind not likely to be made without a due regard for æsthetics.

Thus we hope to grow with a careful regard to the sanitary promises of sound and well ventilated marts as well as those of isolated dwellings. As we all know, every city and country has its individuality, which grows. Our town was obviously born of the union of the fine water power of the Genesee and of the Erie canal. In the early days of forest extermination, the absorbing occupation of the pioneer, the success of the future town was to depend on the exact point at which the magnificent artificial water-way was to cross the river near the water power. Men saw the city rising before them in the dim future, and the advantages of health and gain were urged upon the commissioners appointed by the State to designate the point of crossing, which would accrue to the population if the canal should cross the river about two miles north of its present site. At this place the sanitary condition was excellent, simple drainage being possible at all points. Moreover, in the heart of the town would exist a magnificent harbor, and a much larger amount of water power would be available. But the commissioners replied to those who urged such arguments that their duty consisted in placing the canal where it could be constructed most cheaply. The farmers of Long Island and Dutchess county were perfectly sure that they were to be taxed to pay for the folly of digging "Clinton's Ditch." Thus the difference between $75,000 and $400,000 determined our site, and caused the buildings to be erected and the streets constructed on the unpropitious soil of a black ash swamp. But the energy of the Americans has hardly had a parallel. The swamp was drained and cleared of its forest. To-day we are proud of its sanitary condition, excelled by none, and of a surrounding country unsurpassed in its beauty and fertility. As soon as the trees were felled and removed, the strong triangular harrow was slowly drawn among their stumps and over their roots, loosening up the decaying leaves matted upon the surface. No plough could be used; nor was it necessary. The grain sown broadcast upon this apparently unpromising area, produced forty fold. The wheels of industry rapidly converted this fine grain of the virgin soil into the flour long celebrated as the "Genesee."

Thus we naturally acquired the sobriquet of Flour City.

During the period of the Revolution the great producer of flour was the Brandywine in Delaware. But Rochester carried away the palm which it held for a long time. But we felt the truth of the oft-quoted line, that "Westward the star of empire takes its way." Minneapolis wears our laurels, and although we grind as much grain as formerly we are no longer the Flour City, but the City of Flowers. Incidental to a slight peculiarity of climate, due to the proximity to Lake Ontario, by which young trees and plants can be easily harvested, the industry which produces the useful tree and beautiful flowers has acquired so great proportions as to change our sobriquet which is not likely to be soon altered.

I would like to speak of our parks. But they are only begun and not presentable. The processes of building are never inviting and of them we can see their possibilities which we confidently hope to realize. Our ambition is not confined to the creation of three distinct parks, two upon our rivers at each end of the town; the third perched upon the moraine lying at the southern edge of the city, which gives a magnificent outlook over country and city, with a fountain whose spray consists of the whole water supply of the town. We still hope further to place our jewel in a setting of green—to make a ring-strasse without the razing of a circumvallation. But I will not annoy you with our hopes, recognizing the impropriety of dealing in "futures."

To this town we invite you, hoping that its hospitalities will be pleasing as they are sincere. You will be asked to enjoy our art gallery with a conviction that no superior will be found in these United States, not the possession of the public, but accessible to all. There you will find large collections, pictures by the finest modern artists—productions of Jerome, Knaus and Meisonire.

You will also enjoy the marvellous cabinets of Prof. Henry Ward, whose collections will have special attractions to every devotee of natural science and of whose merits you will be far better judges than myself, unique in its character and unequalled in extent.

And last but not least, we invite you to the halls of our special pride, the University of our city. No body of men could be brought together who would appreciate what such an institution means in elevating and conserving the intellectual status of a community better than that which is before me; none who could better understand the difficulties which surround the early life of such institutions, and usually the slow progress in their development. This has been up to our day their history. The richest and oldest still are straitened for funds to carry out the special restrictions of the bequests that have endowed them. It is only in our day, at this supreme moment, that great schools of learning are emerging, Minerva-like. armed and equipped. It has been wittily said by one who was accomplishing a great undertaking that men had wished for the lamp of Aladdin, but as for him, give him a check on Coutts. That such attention is bestowed upon the people by those who have amassed the colossal fortunes of the last few decades, is merely a hopeful sign of the future. The development of the institutions themselves is also pressing for more facilities, and we cannot but take the optimist view, which is to provide for every one the opportunity for mental and physical improvement. These great fortunes are only the forerunners of greater. That learning will be fostered I feel quite sure, and the trade union that can subvert the doctrine of the survival of the fittest has not yet been organized.

However much the need of money, there is one thing that supersedes it, the intellectual equipment of the teachers. I think our own institution had a beginning quite unique, but still without the great pecuniary endowments alluded to it possessed the Minerva-like quality. It is a by-word with us that the university arrived one day in an omnibus, and when Dr. Kendrick and his colaborers presented themselves for work the college was full fledged. The recitation room might have been in a barn but the university was here. In truth the rooms were adapted to its wants in an abandoned hotel, where it remained for ten years, husbanding resources until it was transferred to its present quarters.

I do not propose any remarks upon university life. This will come from one who will tell its story with words far more fitting than I can employ.

The people of Rochester enter into your designs. The time has nearly gone by when the Philistines can rejoice. The enquirer after pure truth is forgetful of economies in getting to his proper place in popular regard. There is still a poor laggard who in a doubtful tone asks, what use is all this study of pure science for its own sake. but he is no longer the conceited brawler of his ignorance. We sympathize with your efforts, knowing quite well that the seed of truth is like the mustard. The wires along our streets are vibrating like the frog's legs seen by Galvani, but would not have transported our cars or our messages, if he had not learned why. Frauenhofer told us of his lines. Little did he know that he was placing us in touch with the universe. A friend, in speaking of the minute learning of the late Dr. Leidy, narrated the description he gave of a parasite in the liver of a common house fly. I hope some entomologist may teach us how to propagate that parasite and distribute it so as to reach those that infest our houses. It is true that man in his interference with the broad plans of nature has usually erred. The jack rabbit of Australasia is no longer an amusement for the sportsmen. The mongoose has been an admirable agent for the destruction of offensive reptiles in Jamaica, but in the short period of twenty years the balance of life has been altered and the chicken-coop is not the desired field for the mongoose. It is not likely that the tiger will be brought from Bengal to regulate his increase. But I do not hesitate to say that the recent discoveries in bacteriology have done more to relieve or anticipate human suffering than any others in the last twenty years.

Such reflections as these are, however, too trite to be rehearsed to you, and I will close with one word—welcome.

The Hon. RICHARD CURRAN, the Mayor of Rochester, was introduced, and said:—It is customary and not uncommon for the chief magistrate of a city to be called upon to bid welcome or extend hospitality to numerous bodies—including political gatherings, veteran soldier annuals, social conclaves, temperance holdings and liquor dealers' conventions. But it is extremely rare for one to be invited to exercise the pleasure that confronts me to-day, of extending the hospitalities of our city to an organization so justly famous for its varied culture, and so clearly potent for immeasurable good.

I can say to you, ladies and gentlemen, with perfect confidence, that every citizen of Rochester without reserve, even aside from those engaged in scientific work, feels favored and honored by your presence.

While undoubtedly all over this country and especially at the considerable centers of population, great scientific activity is felt, here in Rochester aside from the natural advantages of location and the mental activity exhibited by our rapidly growing population in building fine avenues, in erecting palatial residences and gorgeous business establishments, which marvel and delight the stranger, we can point with pardonable pride to the advances made in scientific research by certain of our population, quietly and without ostentation, which if continued must ultimately ripen into more than national prominence, and give to our city a relative standing far more enviable than all things else.

In 1879, the Rochester Microscopical Society was organized by a few gentlemen. It grew rapidly in favor and in numbers, and soon became the largest of its kind in the United States.

From this beginning sprang the Rochester Academy of Science in 1881, the object being to promote scientific study and research. It was divided into twelve sections, each having its separate organization, and included anatomy, astronomy, botany, entomology, conchology, hygiene, ichthyology, infusoria, literature, microscopy, photography, and taxidermy. The establishment of the academy gave an impetus to the great work here, far beyond all expectations, and served to imbue our citizens with the importance and magnitude of the labor silently carried on in our midst.

Without invidious distinction, the names of a few may be mentioned as illustrative of the growth and popularity of scientific investigation in this vicinity within comparatively recent years.

One of our citizens, a brilliant editor of a leading daily paper, aside from showing that the present tariff is to this nation a star of the first magnitude, finds time to study with marked success, celestial phenomena. I refer to H. C. Maine, who has been a patient and careful observer of the sun for many years, and the conclusions he has drawn as to the connection between solar disturbances and terrestrial meteorology are of great interest and have stimulated research in this direction to a remarkable degree. With instruments of his own manufacture he has successfully photographed the sun and the moon. As a microscopist he has rivalled the famous Mohler in the arrangement of diatom test plates. He has the tenacity and enthusiasm of a true scientist, and will undoubtedly be heard from in the future.

Another of our citizens, Lewis Swift of the Warner Observatory, also a patient observer of the sky, has attained to more than national distinction in his line of research. This ardent student of the science of astronomy, for years, while engaged in the occupation of hardware merchant, devoted every clear night to his favorite study, perched upon an apple barrel on the nearly flat roof of a rickety cider mill. Here, while inhaling the pure air of heaven from above, mingled with the fumes of acetic and pomic acids from below, he scanned the skies night after night with an absurdly inferior instrument. But perseverance and love for the science in the absence of a well-equipped tower, urged him to discovery after discovery, forcing the great astronomers of the world reluctantly to acknowledge the power and genius of the man on the cider mill. He has been first discoverer of ten comets, the last being the most wonderful ever discovered, having twelve tails. His discovery of 970 new nebulæ ranks him with the Herschels in this line of observation. He has been awarded prizes and medals, and has been honored on both sides of the Atlantic to a remarkable degree.

It is scarcely necessary for me to say that this is the home of Professor Ward, the learned biologist, whose labor and undertakings in behalf of science are well known in both hemispheres.

It was here, too, that Lewis H. Morgan lived, labored and died, whose book John Fisk declared to be an epoch-making book.

Some years ago in response to a necessity or growing demand, the University of Rochester began teaching the science of anthropology or the natural history of man to a small class of students. The eagerness or relish for such knowledge soon became felt, and other institutions of learning throughout the country followed the example. But to this university belongs the credit of having first introduced or added in America this important branch to its curriculum. Side by side with scientific labor in this city has grown an optical manufactory of which our citizens are justly proud. In the higher or more scientific branches of optical manufacture the Bausch & Lomb Co. holds a position peculiarly its own. Their first productions were made by their own hands under great difficulties. They now employ in the different branches of their business over 500 operatives.

However it may be in other cities, here, inquiry will show with amazing and pleasing truth, that scientific activity has taken deep root and is with us to stay. From the brain and laboratory of the scientist, mankind is constantly receiving benefits far more precious than jewels.

Were it possible to estimate the value of a man's labor to the world, I believe it would be shown that PRIESTLY, FARADAY and PASTEUR have done more in a material way to relieve suffering, to prolong life, and for the comfort, welfare and happiness of the race than any three men in any other direction since the dawn of Christianity.

Ladies and gentlemen, I crave pardon for having trespassed upon your time, by talking beyond the limit, but as a partial recompense I extend to you with unlimited gladness the freedom of the city.

Dr. DAVID J. HILL, President of the University of Rochester, was then introduced and spoke as follows:—

*Mr. President, Fellows and Members of the Association:*

Ever since it was believed that in opening one's house to strangers one might entertain angels unawares, hospitality has been invested with a mysterious charm. When for the slender chance of an angelic visitor we substitute the certainty of guests of high distinction, the element of mystery is superseded by an irrepressible sentiment of pride. This is our happy lot to-day, for we welcome under our scholastic roof-tree not an unknown multitude in which there may be a few stray angels in disguise, but a company of celebrities of whom it may be said that every member is too well known to furnish concealment to extra-mundane masqueraders. If by chance an inhabitant of Mars should slip in unobserved, no doubt there are those present who could test and determine the validity of his pretensions by a little catechizing on the peculiarities of his native planet. And so we enjoy the double advantage as hosts that, if a messenger from another world were discovered among us, his planetary affiliations would be quickly identified and his knowledge put to scientific use; and, if none should appear, we may at least content ourselves that our own little planet can afford no more worthy or welcome guests than those whom the University of Rochester has the honor to greet to-day.

Every step toward the socialization of science, whether in the persons of its representatives or in the wider diffusion of sympathy with its aims, is to be regarded with delight. The extension of such socialization is an index of scientific progress. When men knew little, they were jealous of their knowledge and held it strictly as private property. How impossible it would have been for the secret-loving alchemists to associate themselves together for the disinterested promotion of science, and to divulge their small discoveries through free mutual interchange. Equally impossible is the solitary and selfish retention of knowledge by contemporary men of science. The history of solid intellectual advancement really began when men first regarded truth as a social possession, the common heritage of mankind. Under the inspiration of this conception, the small philosopher, with his petty system, has practically vanished from the intellectual world, or been relegated to a merely provincial influence; while a public consensus, based on openly verified results, has taken the place of occult doctrines, and is ever widening to the magnitude of a world-conception. The period of esoteric philosophy is past and crypto-science is branded pseudoscience. Specialists have taken the whole race into partnership, or rather regard themselves as special organs of the social body, and the primary instinct of discovery is publicity.

It is largely because it is our business, as a local institution of learning, to socialize knowledge in this community, that we cordially welcome you to these halls and throw open for your use every apartment. We stand—and we wish to be better understood as standing—for the diffusion of knowledge and for its advancement, not for the promulgation of predetermined principles. Above all others in our city, this is the fitting place for such a gathering, convened in the name of widening mental horizons, to hold its sessions. What this association represents in the nation, that this university wishes to represent in this city and its surrounding regions; and yet not in any exclusive sense, for the spirit of monopoly is hostile to this ambition. We point with pride to the scientific institutions of Rochester, such as the Warner Observatory, so ably directed by Professor Swift; the Ward establishment, which supplies so many objects of scientific interest to all parts of the world; the Rochester Academy of Science, which meets in this building; and, indeed, our whole educational system and the many industries representing important forms of applied science.

Your presence here is a great honor to our people, but it should also be a great benefit to them. We need to have impressed upon us the magnitude and dignity of scientific work, and I do not see how the advent of so large a number of the distinguished devotees of science, and the interest that will be taken in your discussions, can fail to leave a profound impression upon our citizens, sustaining the old and awakening a new enthusiasm for the promotion of knowledge.

There is coming to be a better comprehension of the close relation between science, seriously pursued, and the material, political and ethical life of our time. That great critic, Matthew Arnold, accused our age of a deficiency in "intellectual seriousness." Serious enough in the pursuant of its favorite aims our time certainly is, but there is some truth in Arnold's criticism regarding that phase of seriousness which may be called "intellectual." There is, in many minds, a subtle doubt as to the intrinsic importance of truth itself, which leads to a toleration of much that is false. How destructive this is in business, in public affairs and in the growth of character, we all know. Intellectual seriousness is pre-eminently the scientific virtue. It is to modern life what courage was in a militant state of society,—the mother—germ of all the virtues. The serious pursuit of truth transforms the entire existence of a community, whether it be a college or a city. It produces good citizenship whenever its touch falls upon political life, dethroning fraud and enthroning justice. It sweetens and chastens character wherever it enters. In a very real sense, science is salvation. Enough of it to help us to make money, or to shine in conversation, or to obtain any purely selfish purpose, does not, indeed, save; it only ministers to lust or pride. But science in absorbing quantities, taken until it dissolves every passion and every interest in the pure love of truth —truth in thought and truth in action, truth that will not compound with anything false either in conception or in conduct—that is social salvation.

With an almost religious zeal, therefore, the University of Rochester welcomes to these halls dedicated to the molding of manhood, this Association for the Advancement of Science.

President LeConte, in reply to these addresses of welcome, said:—

We have long known of the beauty of Rochester, of its educational advantages. Now we know of the warm-hearted hospitable character of its people. We had a right to expect a welcome, perhaps. This body of scientific men has a right to a welcome from any city. We must love science for its own sake. Truth is its own chief reward. Only it has been mercifully ordered that every step in intellectual progress is also attended by material benefits. Astronomy, while it opens the doors of heaven to our eyes, also guides our navigation. Geology, besides its higher mission of showing the history of planets, also finds for us beds of coal and other minerals. These rewards are only for our encouragement, however. Truth is its own greatest reward. Every community honors itself in honoring science. Gentlemen, I thank you for the heartiness of your welcome.

The Permanent Secretary then read the list of deceased members notices of whose death have been received since the last report. As he read the different names Prof. Putnam made remarks upon the members, their connection with the Association and the more or less active part they had taken in its affairs, dwelling particularly upon the name of Dr. T. Sterry Hunt an original member of the Association and its president in 1870; and upon that of Prof. Joseph Lovering who joined the Association at its second meeting, was the second permanent secretary and its president in 1873.

The Permanent Secretary then read his cash account and account of the funds of the Association for the year past.

The General Secretary announced that the Council recommended that the daily sessions be held on Wednesday, Thursday, Friday, Monday and Tuesday from 10 to 12 o'clock A. M., and from 2 to 5 o'clock P. M. Regularly adopted. He also announced that Hon. S. Dana Horton, Vice President of Section I, was detained in Europe by sickness in his family and that the Council recommended the election of Prof. Lester F. Ward to be Vice President. The recommendation was concurred in. It was then announced that Prof. Ward would deliver an address before Section

I, at the hour for the Vice President's address. Attention was called to the fact that Mr. STEWART CULIN, Secretary of Section H, was in Europe and could not be present at this meeting, and that by the election of Prof. Ward to be Vice President of Section I, there would be two vacancies in the office of Secretary of a Section to fill and that such vacancies would be filled by the Section in the manner provided in the constitution. Attention was called to the announcements on pages 33 and 37 of the daily programme. Announcement was made that 116 members had been elected since the last meeting.

The GENERAL SECRETARY then brought to the attention of the Association the following proposed amendments to the constitution which have laid over from last year:—

To amend article 23 so that it shall read as follows:—

Immediately on the organization of a section, there shall be three fellows elected by ballot after open nomination, who with the Vice President and Secretary, *and the Vice President and Secretary of the preceding meeting*, shall form its Sectional Committee.

The recommendation of the Council is that the proposed amendment be adopted. The amendment was adopted.

The proposed amendment:—

That an article be added to the Constitution, providing that not more than two separate papers by the same member shall be read in any one Section until all other papers which have been accepted shall have been read before said section.

Recommended by the Council that this amendment be not passed.

The recommendation of the Council was adopted.

The LOCAL SECRETARY announced that a daily luncheon would be served at a small cost in one of the rooms of the University set apart for that purpose. He also announced that details of the excursions provided for the members had been printed and would be found in the lobby of the building. The session then adjourned.

EIGHT P.M., SAME DAY. General Session convened in Music Hall, Y. M. C. A. building, PRESIDENT LECONTE in the chair. The retiring President, Professor ALBERT B. PRESCOTT delivered his address (printed in full in this volume).

The GENERAL SECRETARY received the reports of the organization of each Section (these are printed at the beginning of the reports from each section in this volume). In Section H, Rev. W. M. BEAUCHAMP was elected Secretary to fill the vacancy caused by the absence of Mr. STEWART CULIN. In Section I, Mr. HENRY FARQUHAR was elected secretary to fill the vacancy caused by the election of Prof. LESTER F. WARD to be Vice President of that section.

PRESIDENT LECONTE announced an informal reception given by the Y. M. C. A. immediately upon the adjournment of the session. The session then adjourned.

THURSDAY, AUGUST 18, 1892, General Session in the Chapel of the University of Rochester, 10.30 A.M. PRESIDENT LECONTE in the chair.

The GENERAL SECRETARY urged all COUNCILLORS to be present at the Council meeting to-morrow morning at 9 o'clock. He announced total new members elected, 146. Attention was called to the announcement in to-day's programme regarding the discussion, in Section F, of the question of dividing that section into one of Zoölogy and one of Botany.

The SECTIONAL COMMITTEES were requested to meet at noon each day and arrange their programmes for the following day and report the same immediately thereafter to the Permanent Secretary. The following letter from the Eastman Kodak Company was read.

*Eastman Kodak Company.*
*Rochester, N. Y., August 12, 1892.*

SECRETARY OF THE AMERICAN ASSOCIATION FOR
THE ADVANCEMENT OF SCIENCE.

DEAR SIR:

As the advancement of science in photography has undoubtedly interested many members of your society we wish to extend to them an invitation to visit our new film works during their stay in this city. The works are located at Kodak Park, just outside the city limits on the Charlotte Boulevard, and will be open to members of the society Friday afternoon, August 19th, at three o'clock. We feel sure that much that is of interest to scientific people will be found there and hope that it will be convenient for your members to visit the works at that time.

Yours truly,
Eastman Kodak Company,
HENRY A. STRONG,
*President.*

The GENERAL SECRETARY announced that owing to the interference of the hours of meeting, the writer would be requested to change the hour.

The PERMANENT SECRETARY announced that 176 papers had been entered. That the volume of the Washington meeting, unfortunately delayed, is now being distributed from the office of the Association in Salem, Mass.

The LOCAL SECRETARY, Professor FAIRCHILD, requested all who desired to take the excursions arranged for Saturday to register at once with the proper officer in the office of the LOCAL SECRETARY. He also announced that an excursion to Canandaigua on Saturday could be arranged provided a sufficient number desired to go. An expression was called for from those who would like to go. The session then adjourned.

FRIDAY, AUGUST 19, 1892, 10.30 A.M. General Session called to order by PRESIDENT LECONTE.

The GENERAL SECRETARY announced that the COUNCIL desired the reports from all Standing Committees by Monday morning. He announced also that the Council had voted that in future the titles of the Vice Presidents' addresses be sent to the Permanent Secretary as early as possible before the date of the meeting so that the subjects may be printed in the programme of the first day of the meeting.

The proposed amendment to the constitution, "brought over from last year, to amend article 22, line 4, so that the words "F, Biology [G united to Section F]" shall read F, Zoology, G, Botany, was recommended by the Council to pass. The amendment was adopted.

The following letter from the Eastman Kodak Company in reply to the inquiry of the GENERAL SECRETARY was read:

*Eastman Kodak Company,*
*Rochester, N. Y., August 18, 1892.*

AMOS W. BUTLER,
GENERAL SECRETARY,
AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

DEAR SIR:—

Replying to your esteemed favor of this date, it will be perfectly convenient for us to have the visit of your association to our film works postponed until Monday afternoon at four o'clock as you suggest. We hope that a large number of your members will be able to inspect the works at that time.

Yours truly,
EASTMAN KODAK COMPANY,
HENRY A. STRONG,
*President.*

The following letter from the Bausch and Lomb Optical Company was read:—

*Bausch & Lomb Optical Co.,*
*Rochester, N. Y., August 18, 1892.*

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

GENTLEMEN:

We believe that an inspection of our works would be interesting to many of your members, and we cordially invite you to visit them.

We think it would be most practical to you and to us if you would arrange your visit in sections any day convenient for the respective sections from about four to six o'clock in the afternoon.

Hoping that we shall be honored with your visit, we are,

Yours very respectfully,
BAUSCH & LOMB OPTICAL CO.,
EDW. BAUSCH.

The Secretaries were requested to report promptly to the General Secretary the time the several sections would prefer to visit the works referred to.

It was announced that 163 members had been elected up to this time.

The LOCAL SECRETARY requested all persons desiring to participate in the excursions to register at once, also that the certificates entitling members to reduced fare returning from the meeting should be left with the Railroad Secretary without delay. The session then adjourned.

SAME DAY, 8 P.M. General Session called to order in Music Hall, Y. M. C. A. building by PRESIDENT LECONTE. He introduced Dr. JOSEPH JASTROW, of the University of Wisconsin, who delivered an illustrated lecture complimentary to the citizens of Rochester on "Hypnotism and its Antecedents." The session then adjourned.

SATURDAY, AUGUST 20. This day was given up to excursions as follows:
To Niagara Falls and Lewiston, by special train leaving at 8.15 A.M.

To Portage and Mount Morris, by special train leaving at 8 A.M.

To Stony Brook Glen, by special train leaving at 8 A.M.

To Canandaigua Lake, by regular train leaving at 8.10 A.M. These excursions are fully described in the special circular of the Local Committee. They were largely attended and were in every respect successful and greatly appreciated and enjoyed by the members of the Association.

MONDAY, AUGUST 22, 1892. The Association was called to order in General Session at 10.30 o'clock A. M., by PRESIDENT LECONTE.

The GENERAL SECRETARY announced the COUNCIL recommended that each section appoint a committee of not less than five to coöperate with corresponding committees of the World's Congress Auxiliary of the Columbian Exposition and that the sections report their action to the COUNCIL on Monday evening.

That all members put into the hands of the Secretaries of their respective sections the abstracts of their papers ready for printing.

Also that Elwanger and Barry's nurseries were open to the members of the Association during business hours, each day.

The GENERAL SECRETARY read the report of the Committee on Data for the Determination of the Secular and Periodic Changes of Terrestrial Latitudes, and stated that the COUNCIL recommended the reception and printing of the report without further action and that the committee be discharged. Adopted.

## REPORT OF THE LATITUDE COMMITTEE.

The committee of the American Association for the Advancement of Science appointed at the Washington meeting to consider and report upon a proposed investigation of possible secular changes of terrestrial latitudes respectfully submits to the Association the following report:

While considerable differences of opinion exist among members of the committee with respect to the probable existence of such changes and in a minor degree with respect to the wisdom of undertaking such an investigation at the present time on account of the expense involved, the members of the committee are agreed that if such an investigation is to be made the best method of attacking the problem is by observations at three or more stations upon approximately the same parallel of latitude, but situated in widely different longitudes. The same stars should be observed at all of the stations with similar instruments, and the observations should be extended over a sufficient interval of time to secure the elimination of any effect arising from the recently discovered short period variations in the latitude. Such a series of observations followed after an interval of from ten to twenty years by another similar series would furnish better evidence in regard to the existence of secular changes of latitude than can be obtained without such coöperation in research, but the complete execution of this program would require the establishment of at least one observing station upon the eastern coast of Asia, and in the existing condition of the problem it may be questioned if the expense thus involved would be justified by the probable returns.

Such observations at European and American stations can probably be obtained with no great difficulty, especially if the coöperation of the International Geodetic Association can be secured, and will doubtless furnish better material for the purpose in question than any now extant. Nevertheless it seems advisable to utilize so far as possible some of the older determinations of latitude at American stations, particularly the Bond-Pierce determination at Cambridge in 1845 and the earlier Coast Survey determinations. At the request of Professor Pickering, Director of Harvard College Observatory, Prof. William A. Rogers will redetermine the latitude of Cambridge by a method similar to that employed by him in 1864, and the Superintendent of the Naval Observatory has expressed his willingness to institute a new series of observations with the Washington prime vertical transit for comparison with its earlier work and to control the results furnished by this instrument by simultaneous observations with a zenith telescope. Both the Washington and Cambridge work thus proposed seem to your committee eminently desirable and to promise substantial contributions to the solution of the problem under consideration, but the sources of error in such an investigation are so numerous and the quantities to be determined so minute that it does not appear superfluous to supplement these investigations by the redetermination of a considerable number of zenith telescope latitudes observed twenty or more years ago. In this redetermination every care should be taken to make the new observations comparable with the older ones by reobserving, if possible. the same pairs of stars, and by so selecting the times of observation that the effect of the periodic changes of latitude may be as nearly as possible eliminated.

The committee therefore submits to the Association the following recommendations:

I. That a committee of the Association be appointed to confer with the International Geodetic Association with a view to securing simultaneous latitude determinations by similar methods at permanent stations upon nearly the same parallel of latitude in Europe and America.

II. That the committee be further authorized to request the Superintendent of the U. S. Coast and Geodetic Survey to institute, if practicable, a redetermination of a considerable number of latitudes of such stations upon both the Atlantic and Pacific coasts as in his judgment are best adapted to furnish reliable indications of a secular change in latitudes, if any such exist.

III. That this committee be instructed to ascertain if a redetermination of the latitudes of the U. S. Lake Survey stations, Minnesota Junction, Wis., and Willow Springs, Ill., can be secured through either public or private coöperation.

[Prof. SIMON NEWCOMB absent. Letter substantially approving the report here appended. Dr. B. A. GOULD declined to sign.]

T. C. MENDENHALL.
T. C. CHAMBERLIN.
F. V. MCNAIR.
R. S. WOODWARD.
C. L. DOOLITTLE.
GEO. C. COMSTOCK.

NAUTICAL ALMANAC OFFICE, NAVY DEPARTMENT,
*Washington, D. C., March* 4, 1892.

Prof. T. C. MENDENHALL,
Supt. U. S. C. and G. Survey,
Washington, D. C.

DEAR SIR:—

In reply to yours of March 1st, enclosing résumé of opinions, and first draft of recommendation, I beg leave to submit the following remarks:

I. My own opinion was indicated before I had been made acquainted with the nature of the theory to be tested. So far as regards the nature of the problem, I now agree substantially to the most important points of the opinion expressed by Professor Comstock, that the best way of attacking the problem is by observations at three stations, somewhere near the same parallel of latitude, but in widely different longitudes, using similar instruments, star places, and methods of observation. I should think that the work now believed to be going on under the auspices of the European Geodetic Association, and your own office, would furnish a sufficient basis for the work necessary at the present epoch.

As to the recommendations, it seems to me very largely a matter of expense, and available funds. The redeterminations certainly seem worth making on our own coast, but I should not deem it advisable to send special expeditions to Eastern Asia to redetermine the latitudes of the Transit of Venus stations. If, however, such a determination could be made in connection with some other desirable work, it ought to be included.

Very respectfully,
S. NEWCOMB.

Attention was called to the report of the Committee on Biological Nomenclature, which was presented printed. Upon motion the report was received and the Committee continued.

The following resolutions from the Committee on Indexing Chemical Literature were read and adopted:

*Whereas*, There is a great want of a subject-index to the catalogue of the Scientific Papers published by the Royal Society, therefore

*Resolved*, That the President of the American Association for the Advancement of Science be requested to communicate with the President of the Royal Society to ascertain whether such subject-index is to be published, and if a negative reply be received, and the consent of the Royal Society be secured, *Resolved*, That the President of the American Association for the Advancement of Science be requested to urge upon the several Vice Presidents of this Association their coöperation in obtaining the services of experts in each Section for the preparation of a subject-index, with the expectation of its publication by the Smithsonian Institution.

H. CARRINGTON BOLTON,
ALBERT B. PRESCOTT,
ALBERT R. LEEDS,
ALFRED TUCKERMAN.

The following letter was read, from Prof. WM. A. ROGERS.

*Rochester, N. Y., August* 22, 1892.

Prof. F. W. PUTNAM,
PERMANENT SECRETARY A. A. A. S.

DEAR SIR:—

In the absence of Prof. Morley the undersigned respectfully begs leave to report that the appropriation of $100 made at the last meeting of the Association to Professors Morley and Rogers has been expended by the undersigned in constructing apparatus designed for the determination of the absolute coëfficients of expansion of metals between the limits 0° and 100° C. *in vacuo*, expressed in terms of wave lengths of light of a given refrangibility. This apparatus, which has been constructed at an expense a little exceeding $900, is now placed in position in the equal temperature room of the physical laboratory of Colby University, and it is expected that Prof. Morley will reach Waterville by Sept. 1, when the projected experiments will be undertaken. This report, therefore, is to be regarded as preliminary to a more full report, which will be made at a subsequent meeting of the Association.

Respectfully submitted,
WM. A. ROGERS.

Under a resolution adopted by Section F (see proceedings of Sec. F) in relation to the proposed Biological Station in Jamaica, requesting the appointment of a committee to report, at the next meeting of this Association, a plan for the establishment of a table there; upon motion the following committee was appointed: Prof. A. H. TUTTLE, Prof. E. S. MORSE, Dr. B. D. HALSTED, Dr. C. W. STILES, Dr. N. L. BRITTON.

At the request of Section H the COUNCIL recommended the appointment of Mr. W. H. HOLMES, Dr. D. G. BRINTON, Prof. F. W. PUTNAM, Prof. O. T. MASON and Mr. A. W. BUTLER to be a committee to memorialize the city authorities of Anderson, Ind., and the legislature of Indiana for the purchase and preservation of the earthworks near the city of Anderson, Indiana. The committee was regularly appointed.

Announcement was made that there would be a business meeting of Section D after the adjournment of this session.

By request of the Bausch and Lomb Optical Co. notice was given that they would be pleased to have the members of the Association visit them at any time during business hours Monday, Aug. 22 and Tuesday, Aug. 23.

The Committee to apply to Congress for a Reduction of the Tariff on Scientific Books and Apparatus reported progress. The report was received and the Committee continued.

The LOCAL SECRETARY announced that arrangements had been made for an excursion down the River St. Lawrence to Montreal, also one to the Northern Adirondack Wilderness, both at reduced rates and subject to a sufficient number desiring to go. Persons wishing to take part in either of these excursions were requested to register with the Excursion Committee as early as possible. The session adjourned.

SAME DAY, 8 O'CLOCK, P. M. The Association met in Music Hall, Y. M. C. A. Building, to attend a lecture given under the auspices of the ROCHESTER ACADEMY OF SCIENCE, by Mr. G. K. Gilbert; subject:—"Coon Butte and the theories of its origin."

TUESDAY, AUGUST 23, 1892. General Session in the Chapel of the University of Rochester at 10.30 o'clock. PRESIDENT LECONTE in the chair.

The following report of the Committee on Forestry was presented.

REPORT OF COMMITTEE ON FORESTRY.

Your committee reports that, while as a body it has not any action of its own to record, its individual members have watched and assisted the progress of forest legislation.

As a result of the law passed in March, 1891, the President of the United States has used the power conferred on him by the law in reserving five distinct tracts of public timberlands. In addition several large areas in various States have been temporarily withdrawn from market, pending examinations prior to their reservation.

A bill providing for the reservation of all public timberlands and their proper administration under the Secretary of Agriculture was introduced during the last season of Congress by Senator Paddock (S. 3235) referred to a select committee, specially constituted for the purpose, reported back favorably and placed upon the calendar. It has, thereby, become privileged to be called up early next session. Your committee fully approves of the provisions of the bill. In view of this favorable situation and since it is believed that the existence of this committee representing the Association on the forestry question may become of benefit in advancing this legislation during the next session, the committee asks to be continued.

For the Committee,

B. E. FERNOW, *Secretary*.

Upon motion the report was received and the committee continued.

The following resolutions from Section I were read and recommended by the COUNCIL for adoption.

*Whereas*, The United States government retains as public property a large forest area in locations where its conservative management is of national importance, and

*Whereas*, Such conservative management as is needed can practically be carried on only by the government itself:

*Resolved*, That it is the sense of this Association, advised by its committee on Forestry, that such legislation as is embodied in the bill introduced and reported by Senator Paddock (S. 3135), which provides for reservation and practical administration of the public timber domain, is deserving the endorsement and commendation of the American Association for the Advancement of Science.

*Resolved*, That duly signed copies of this resolution be sent to the President, the presiding officer of the Senate, and the Speaker of the House of Representatives.

The resolutions were adopted.

The Committee on Water Analysis reported that it had made a report of progress to Section C and asked its continuance. The Committee was accordingly continued.

The Committee to Memorialize Congress to take steps for the Preservation of Archæologic Monuments on the Public Lands reported progress. The report was received and the Committee was continued.

Upon motion, Mr. HENRY GANNETT was re-elected as Honorary Agent of transportation to act with the Local Committee.

The Committee to secure an American Table at the International Marine Biological Station at Naples, Italy, reported progress to Section F and asked to be continued with the following change in the membership of the committee; instead of Mr. B. E. FERNOW who resigned, Prof. E. D. COPE of Philadelphia. Upon motion the Committee was continued.

The Committee on Standard Instruments for Astronomical and Physical Research reported as follows:

The Committee on Standards for Astronomical and Physical Instruments begs to report progress. Considerable correspondence has been carried on with various manufacturers of these instruments, and data have been collected of value during the past year, and it is certainly a matter of importance to continue the committee.

Respectfully,

J. A. BRASHEAR, *Mem. of Committee.*

Upon motion the report was received and the Committee was continued.

The Committee on the Endowment of the Research Fund reported progress. Upon motion the Committee was continued.

The GENERAL SECRETARY announced the following Fellows had been elected by the COUNCIL:

Abbe, Robert, 11 W. 50th St., New York, N. Y. (36). F
Ashmead, Wm. H., 825 Vermont Ave., Washington, D. C. (40). F
Atkinson, George F., Auburn, Ala. (39). G
Bauer, Louis A., U. S. C. and G. Survey, Washington, D. C. (40). A
Bixby, Wm. H., Capt. of Eng., U. S. A., Newport, R. I. (34). D
Bolley, Henry L., North Dakota Agric. College, Fargo, N. D. (39). G
Casey, Thomas L., Room 79, Army Building, 39 Whitehall Street, New York, N. Y. (38). F

Conant, Prof. L. L., Clark University, Worcester, Mass. (39). A H
Cook, Prof. Orator F., Clyde, N. Y. (40). F
Craighill, Col. Wm. P., 9 Pleasant St., Baltimore, Md. (37). D
Dorsey, George A., Peabody Museum, Cambridge, Mass. (39). H
Fairchild, David G., Dept. of Agric., Washington, D. C. (40). G
Fargis, Rev. Geo. A., Georgetown College, Georgetown, D. C. (40). A
Franklin, William S., Ames, Iowa (36). B
Goldsmith, Edw., 658 North 10th St., Philadelphia, Pa. (29). C E
Greely, Adolphus W., Signal Office, Washington, D. C. (39.) I
Griffith, Ezra H., 28 Meigs St., Rochester, N. Y. (39). B F
Hitchcock, Albert Spear, Manhattan, Kansas (39). G
Hollick, Arthur, Box 105, New Brighton, Staten Island, N. Y. (31). G E
Holm, Theodor, U. S. National Museum, Washington, D. C. (40). G
Howard, Prof Curtis C., 115 Jefferson Ave., Columbus, Ohio (38). C
Jacoby, Henry S., in charge of Bridge Engineering and Graphics, College of Civil Eng., Cornell Univ., Ithaca, N. Y. (36). D
King, F. H., Experiment Station, Madison, Wis. (32). E F
Lawson, Dr. Andrew C., University of California, Berkeley, Cal. (38). E
Lindal, Joshua, Ph.D., State Geologist, Springfield, Ill. (40). F E
McAdie, Alexander George, Weather Bureau, Washington, D. C. (40). B
McGee, Mrs. Anita Newcomb, U. S. Geol Survey, Washington, D. C. (37). H
McGregory, Prof. J. F., Hamilton, N. Y. (35). C
Marlatt, Charles L., 1519 Rhode Island Ave., Washington, D. C. (40). F
Marvin, C. F., Signal Office Washington, D. C. (39). B
Maxwell, Walter, Dept. of Agriculture, Washington, D. C. (40). C
Millspaugh, C. F., M.D., Morgantown, W. Va. (40). G
Mohr, Dr. Charles, Mobile, Ala. (40). G
Moler, Geo. S., 106 University Ave., Ithaca, N. Y. (38). B
Moody, Robert O., Fair Haven Heights, New Haven, Conn. (35). F
Moore, Veranus A., M D., Bureau of Animal Industry, Dept. of Agric., Washington, D. C. (40). F
Nutting, Prof. Charles C., State Univ. of Iowa, Iowa City, Iowa (40). F
Pammel, Prof. L. H., Iowa Agric. College, Ames, Iowa (39). G
Peary, Robert E., C. E., U. S. N., United States Navy Yard, League Island, Philadelphia, Pa. (36). D
Rathbun, Richard, U. S. National Museum, Washington, D. C. (40). F
Reese, Charles L., 1801 Linden Ave., Baltimore. Md. (39). C
Ridpath, John Clark, Greencastle, Ind. (39). H
Rosa, Edward Bennett, Associate Prof. of Physics, Wesleyan Univ. Middletown, Conn. (39). A B
Russell, Thomas, Signal Office, Washington, D. C. (39). B
Sabine, Wallace Clement, Harvard College, Cambridge, Mass. (39). B
Safford, Prof. Truman H., Williams College, Williamstown, Mass. (41). A
Saville, Marshall H., Peabody Museum, Cambridge, Mass. (39). H
Schwarz, E. A , U. S. Dept. of Agric., Washington, D. C. (29). F
Shelton, Prof. Edward M., Dept. of Agric., Brisbane, Queensland, Australia (32). F

Shufeldt, Dr. R. W., Smithsonian Inst., Washington, D. C. (40). F
Smith, Alex., Ph.D., Crawfordsville, Ind. (40). C
Snow, Julia W., La Salle, Ill. (39). G
Speyers, Clarence L., Columbia, Mo. (36). C
Starr, Frederick, Ph.D., Univ. of Chicago, Chicago, Ill. (36). H E
Stedman, Prof. John M., Trinity Univ., Durham, N. C. (40). F
Steele, Miss Maria O., 138 Montague St., Brooklyn, N. Y. (35). G
Steinmetz, Chas. Proteus, 124 Waverly Place, Yonkers, N. Y. (40). B
Stejneger, Leonhard, Curator Dept. of Reptiles, National Museum, Washington, D. C. (40). F
Stiles, Dr. Chas. W., Dept. of Agric., Washington, D. C. (40). F
Sturgis, Wm. C., 384 Whitney Ave., New Haven, Conn. (40). G
Swingle, W. T., Dept. of Agric., Washington, D. C. (40). G
Thwing, Charles B., Northwestern Univ., Evanston, Ill. (38). B
Warner, Prof. A. G., Leland Stanford Jr. Univ., Palo Alto, Cal. (38). I
White, David, U. S. Geol. Survey, Washington, D. C. (40). E F
Wilson, Herbert M., U. S. Geol. Survey, Washington, D. C. (40). D E

The General Secretary announced the Council had granted the following applications for money from the income of the research fund.

To Prof. Edward Hart $100 to aid him in the reduction of the metal glucinum.

To Prof. Joseph Jastrow $100 to aid him in psychological research in connection with the World's Fair.

To the Committee on American Table at the Marine Biological Laboratory at Naples $100, provided the committee raise $400 additional for that purpose.

The General Secretary read the following letters:

*Omaha, Neb., Aug. 13, 1892.*

Secretary American Association for the Advancement of Science.

My dear Sir:

Permit me as Secretary of the Omaha Scientific Association to extend through you to the American Association a most cordial and hearty invitation to hold your next annual meeting in our young but growing city.

Such a decision on your part would do much to advance scientific thought among us and we in return can promise to care well for you while here.

I am, most respectfully yours,

S. R. Towne.

*San Francisco, July 27, 1892.*

Prof. F. W. Putnam,

Dear Sir:

The following is a true copy of Resolution No. 7047 (Third Series) adopted by the Board of Supervisors of the city and county of San Francisco, California, at their meeting held on Monday evening, July 25, 1892.

"Resolution No 7497 (Third Series). *Resolved*, that the Board of Supervisors of the city and county of San Francisco does hereby extend to the American Association for the Advancement of Science an invitation to hold its annual meeting in 1895 in this city, assuring them at the same time of a most cordial welcome from all our citizens."

Respectfully,

Jacob Russell, *Clerk*,

W. Z. Patterson, *Deputy*.

*Berkeley, Aug. 8, 1892.*

DEAR PROFESSOR LECONTE:

At a meeting of our Academic Council it was unanimously voted to join in an invitation to the American Association for the Advancement of Science, to hold its annual meeting for 1895 in the city of San Francisco. A Committee was appointed to solicit coöperation in this matter from the Stanford University, the California Academy of Sciences, and the City Government of San Francisco. It is understood that those, and perhaps other institutions, will transmit invitations parallel with ours.

Will you, as a member of this Committee, and in behalf of our University, tender such an invitation to the A. A. A. S., over which you are this year to preside?

For the Committee,

MARTIN KELLOGG, *Act'g Pres't Univ. Cal.*

*Leland Stanford Junior University, Palo Alto, Cal., July 24, 1892.*

TO THE SECRETARY OF THE A. A. A. S.

SIR:

The Faculty of the Leland Stanford Junior University begs to extend to the American Association for the Advancement of Science a most cordial and urgent invitation to hold its annual meeting in 1895 in the city of San Francisco, Cal.

We assure you we shall be delighted to do all in our power as an institution of learning, as a faculty, and as individuals to make the visit of the Association on that occasion a pleasant and a profitable one.

On behalf of the Faculty,

JOHN C. BRANNER,
J. M. STILLMAN,
CHAS. D. MARX.

*San Francisco, Cal., August 10, 1892.*

TO THE COUNCIL OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, ROCHESTER, N.Y.

SIRS:

The California Academy of Science begs to invite the American Association for the Advancement of Science to hold its annual meeting in 1895 in the city of San Francisco.

The Academy will be glad to extend the privileges of its lecture room, library and collections to the Association, to assure its members of a most cordial welcome, and to do all in its power to make this meeting in this city a pleasant and profitable one.

With respect,

H. W. HARKNESS, M.D. *President.*
J. R. SCUPHAM, *Secretary.*

*Chicago Academy of Sciences, Chicago, U. S. A., August 12, 1892.*

TO THE PRESIDENT AND COUNCIL OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

GENTLEMEN:—

The undersigned, in behalf of the Chicago Academy of Sciences and by its order, most respectfully and most cordially invite the American Association for the Advancement of Science to hold its meeting for the year 1893 in the city of Chicago. The magnitude and perfection of the preparations for the coming Exposition, the most complete, as it will be the latest material presentation of the World's progress, —the concrete expression of the most advanced and the noblest civilization; the jubilee which will gather from all nations the representatives of every phase of human progress; these and other items which we need not cite to your intelligence, serve to forecast the grandeur of an occasion which will not be rounded into the fullest expression of American progress without the presence of America's largest and most renowned society of scientific investigators.

We therefore express the earnest hope of the Academy of Sciences that you will find it consonant with the dignity of your great Association, and with the pleasure of its membership, so to arrange the time, place and manner of your next meeting as will, in Chicago, enable Columbia to welcome with you and through you a noble confederation of the scientists of the world.

We present in the name of the Chicago Academy of Sciences our most obedient service.

SELIM H. PEABODY, *President.*

WM. K. HIGLEY, *Secretary.*

TO THE PRESIDENT OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

SIR: On behalf of Northwestern University I desire to extend a cordial invitation to the Association to hold its next annual meeting in Chicago, and beg to assure you that should the Association decide to hold its meeting in Chicago, it will be heartily welcomed by all the educational and literary bodies of this vicinity, and that everything will be done that can be done to promote the success of the meeting, and the comfort and happiness of those who participate therein.

Respectfully yours,

HENRY WADE ROGERS.

*Chicago, U. S. A., Aug. 17, 1892.*

TO THE OFFICERS AND MEMBERS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, IN SESSION AT ROCHESTER, N. Y.

The World's Congress Auxiliary of the World's Columbian Exposition was organized to bring about a series of World's Congresses at Chicago, during the Exposition Season of 1893, in which the progress of mankind, in all departments, will be appropriately set forth, and in which the living questions of the day relating to such progress will be properly considered.

The World's Congress Auxiliary is the properly accredited representative, not only of the Exposition authorities, but also of the Government of the United States, for arranging and conducting the proposed series of International Congresses. The diplomatic and consular officers of the United States in all countries have been directed by the Department of State to present the publications of the auxiliary to the governments to which they are respectively accredited, and invite them to appoint official delegates to all or any of the Congresses, in addition to the representatives who are expected from the various societies and institutions of different countries.

In pursuance of the plans adopted upon its organization, the World's Congress Auxiliary has invited the scientific societies of all countries to attend and participate in the Congresses of the Department of Science and Philosophy, which are included in the World's Congress Scheme.

As it is obviously impossible to provide for separate and independent meetings of all the various learned societies whose coöperation is expected, and as it would be discourteous to foreign societies to make more favorable arrangements for societies of our own country than for those of other countries, it is a matter of necessity as well as of wise choice that all societies of a given kind throughout the world be invited to unite in a World's Congress on the subject involved, in place of the usual annual meetings of such associations. In those Worlds' Congresses, whether general or special, the members of all learned societies will meet with equal rights and privileges and honors. But to this rule it seems necessary to make a single exception. To save existing societies the trouble and expense of holding separate meetings in another place, for the purpose of transacting their strictly necessary business, such as receiving the reports of officers, appointing committees for the next year, etc., the Auxiliary will, though at considerable inconvenience, endeavor to arrange brief sessions for the transaction of such necessary business by attending societies.

While the World's Congress Auxiliary, as an American organization, is very desirous to reserve the best opportunities and the highest honors of the Congresses of 1893 for the eminent societies and individuals of other countries, who will honor them with their attendance and participation, the Auxiliary, at the same time, earnestly desires and solicits the active coöperation and aid of all appropriate American societies in the great work it has undertaken.

Provision for such coöperation and aid has long since been made. Each Congress is in charge of a local committee of arrangements assisted by an advisory council of eminent persons, selected from the different countries of the world. All appropriate existing societies and institutions are cordially invited to appoint their respective committees of coöperation, to assist the Committee of Arrangements and Advisory Council in making the arrangements for the several Congresses. These committees of coöperation will be recognized by the Auxiliary as the appropriate representatives of the institutions or organizations by which they are appointed; and will be welcomed to a direct and active participation in the World's Congress work. The idea of the Auxiliary is to recognize and honor in every appropriate way the learned societies of its own country, with the proper deference above mentioned to foreign societies.

With these explanations of its plans and purposes, a cordial invitation is hereby extended by the World's Congress Auxiliary to the American Association for the Advancement of Science, and to the various organizations connected therewith, to attend and participate in the Congresses to be held in the Department of Science and Philosophy, in connection with the World's Columbian Exposition, in July or August of next year. The exact date is under consideration, and will soon be announced.

Your Association is invited to appoint, not only a committee of coöperation on behalf of your whole organization, but special committees of coöperation for the various sections of your body, in order that the Auxiliary may have the benefit of the advice and assistance of such committees in the preparation of programmes for the various Scientific Congresses of 1893.

Any additional explanations which may be desired will be made by chairmen of the Auxiliary committees, some of whom will be in attendance on the meeting of your Association.

With a high appreciation of the long and distinguished career of your Association, and sincere respect for its officers and members, I have the honor to be,

Very sincerely yours,

CHARLES C. BONNEY, *President World's Congress Auxiliary.*

*Rochester, N. Y. Aug. 18, 1892.*

TO THE COUNCIL OF THE A. A. A. S.

GENTLEMEN:

At a meeting of the Wisconsin Academy of Sciences, Arts and Letters, held at Green Lake, Wis., June 4, 1892, it was voted to extend to the American Association for the Advancement of Science a cordial invitation to hold its annual meeting of 1893 in the city of Madison, the headquarters of the Academy.

WM. H. HOBBS, *Secretary.*

*Madison, Wis., June 24, 1892.*

F. W. PUTNAM, SECRETARY,
SALEM, MASS.

DEAR SIR:

I am directed by the Board of Regents of the University of Wisconsin to extend to the Council of the American Association for the Advancement of Science, its most cordial invitation to hold the annual meeting of the Association for 1893 in Madison, Wisconsin, and tender to it the use of our University buildings and facilities for such meeting.

Very respectfully,

E. F. RILEY, *Secretary.*

*Madison, Wis., Aug. 17, 1892.*

F. W. PUTNAM, ESQ., ROCHESTER, N. Y.
PERMANENT SECRETARY, A. A. A. S.

DEAR SIR:

By directions of our Mayor and Common Council I beg to enclose a copy of resolution adopted by the council of our city at its last regular meeting, inviting your Association to hold its next meeting in this city.

Hoping the Association may find it convenient to accept the invitation, most cordially extended, I remain

Yours truly,
O. S. NORSMAN, *City Clerk.*

"By Ald. Heyl:

*Be it Resolved,* That the Mayor and Common Council of the city of Madison, Wisconsin, desire to renew to the American Association for the Advancement of Science their cordial invitation to hold its forty-second annual meeting (1893) in this city.

We beg to assure the Association that the citizens of Madison will feel honored by the acceptance of this invitation, and will heartily coöperate in providing the usual facilities for the meeting.

On motion of Ald. Heyl the rules were suspended and the resolution adopted unanimously."

It was voted that all the invitations read be received and gratefully acknowledged.

The GENERAL SECRETARY announced that the NOMINATING COMMITTEE recommended that the next meeting of the AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE be held in the city of MADISON, WISCONSIN, beginning on the third Thursday in August, 1893, and that the COUNCIL be given authority to change the date if such action is found to be desirable. The recommendation was unanimously adopted.

The following fellows were recommended by the NOMINATING COMMITTEE as officers for the next meeting.

*President:* WILLIAM HARKNESS, Washington, D. C.

*Vice Presidents:* Section A, C. L. DOOLITTLE, South Bethlehem, Pa. B, E. L. NICHOLS, Ithaca, N. Y. C, EDWARD HART, Easton, Pa. D, S. W. ROBINSON, Columbus, O. E, CHAS. D. WALCOTT, Washington, D. C. F, HENRY F. OSBORN, New York, N. Y. G, CHARLES E. BESSEY, Lincoln, Neb. H, J. OWEN DORSEY, Tacoma, Md. I, WILLIAM H. BREWER, New Haven, Conn.

*Permanent Secretary:* F. W. PUTNAM, Cambridge (office Salem), Mass. [holds over]. *General Secretary:* T. H. NORTON, Cincinnati, Ohio. *Secretary of the Council:* H. L. FAIRCHILD, Rochester, N. Y.

*Secretaries of the Sections:* A, ANDREW W. PHILLIPS, New Haven, Conn. B, W. LECONTE STEVENS, Troy, N. Y. C, J. U. NEF, Chicago, Ill. D, D. S. JACOBUS, Hoboken, N. J. E, ROBERT T. HILL, Austin, Tex. F, L. O. HOWARD, Washington, D. C. G, F. V. COVILLE, Washington, D. C. H, WARREN K. MOORHEAD, Xenia, O. I, NELLIE S. KEDZIE, Manhattan, Kan.

*Treasurer:* WILLIAM LILLY, Mauch Chunk, Pa.

The Secretary was unanimously authorized to cast the ballot of the Association for the election of the persons nominated. The chair declared them duly elected.

The following statement in the form of a proposition was read by the GENERAL SECRETARY:

That the American Association for the Advancement of Science appoint a committee with the power to act for the purpose of conferring with the authorities of the World's Columbian Exposition, for the use of special rooms for each of the sections of the American Association for the Advancement of Science, during the entire period of the Exposition. The rooms to be in the buildings containing the exhibits most closely allied to sciences of the respective sections, to be used as a headquarters for members visiting the Fair, and for the entertainment of those interested in the same sciences in the United States and abroad.

The members to use the rooms for the reception of mail matter, as a visiting place, reading room and to entertain the visiting members whose whereabouts could be readily ascertained if a register were kept in each room.—GEORGE F. KUNZ.

Upon motion a committee consisting of the Secretaries of the Association and of the several Sections for next year was appointed to confer with the authorities of the World's Columbian Exposition, with a view to effecting the arrangements proposed by Mr. Kunz.

Upon motion of Prof. F. W. PUTNAM, the greetings of the Association were sent to Mrs. MARY KING, of 35 Madison street, Rochester, N. Y., the oldest living member of the Association. Mrs. King is ninety-three years old and on account of feeble health was unable to attend the meetings of the Association this year.

The session then adjourned.

In the afternoon there was a short excursion to the State fish hatchery, at Mumford, which was quite largely attended, as the Sections finished their work and adjourned at noon.

SAME DAY; 8.30 P. M. The concluding General Session of the Association was held in Music Hall, Y. M. C. A. building, PRESIDENT LECONTE in the chair.

The following communication was read, but owing to the fact that it had not come in the regular way, before the COUNCIL, no action could be taken.

*Rochester, N. Y., Aug.* 23, 1892.

In the absence of a national flower it is suggested that the American Association for the Advancement of Science embody among its resolutions passed with reference to the Columbian Exposition, a request to adopt the Columbine as the flower of the fair; leaving the national flower, whatever it prove to be, to grow in popularity.

Its name comes from the same root as Columbia, a name our country often bears; it is classed with the "*Aquilegia*," or Eagle variety, because its petals end in spurs resembling the talons of an eagle; it grows in red, white and blue, our national colors; it has five trumpet-shaped petals, corresponding to the five points of the star upon our flag, and these are grouped around a central shaft, similar to the arrangement of the States around the central government; and it is indigenous to the North American continent, a hardy perennial and wild flower that is found in every part of our land, growing even upon the Rocky mountains in the very heart of the country.

The Columbine is appropriate in name, color and form. Its name suggests Columbia; its colors are the colors of Columbia; and its form is the prototype of the Phrygian liberty cap, the head-dress of Columbia, and is a copy of the cornucopia, the symbol of the Columbian Exposition.

It would be a living monument with which to commemorate the national event.—T. T. SWINBURNE.

Prof. F. W. PUTNAM, the **PERMANENT SECRETARY**, made the following statistical report of the meeting.

There have been presented addresses and papers as follows:— 1 President's address; 8 Vice President's addresses; 4 Reports and several other reports of progress; 1 public lecture, 24 papers in Section A, 21 in B, 20 in C, 15 in D, 19 in E, 57 in F, 35 in H, 7 in I; making a total of 198 papers read out of 208 received. A new Section has been formed for Botany, to be known as Section G. 65 fellows were elected; 175 members were elected. 456 members and associates registered from the following places: — Rochester, 32; New York State (other than Rochester), 103; Washington, D. C., 53; Ohio, 35; Pennsylvania, 29; Massachusetts, 24; Indiana, 22; Illinois, 20; Canada, 18; Michigan, 16; Connecticut, 13; New Jersey, 11; Iowa, 10; Wisconsin, 10; Missouri, 6; Kentucky, 5; Tennessee, 5; Maryland, 5; Alabama, 5; Georgia, 3; Vermont, 3; New Hampshire, 3; Maine, 3; California, 3; Minnesota, 2; West Virginia, 2; Florida, 2; Louisiana, 2; Mississippi, 2; Rhode Island, 2; North Dakota, 1; Kansas, 1; Texas, 1; Virginia, 1; North Carolina, 1; and from Hungary, 2.

The following resolutions were read by the **GENERAL SECRETARY**, who moved their adoption.

*Whereas*, The Rochester meeting of the American Association for the Advancement of Science, ending this evening, has been a notably successful and profitable one, and one which will long be remembered with pleasure by those who participated in it; and,

*Whereas*, The success, profit and pleasure of the meeting have largely grown out of the generous hospitality, the untiring energy, and the constant aid of certain individuals and institutions; therefore,

*Resolved*, That the cordial and hearty thanks of the Association shall be and are hereby tendered,

1. To the municipal authorities of the city of Rochester, for their kindly invitation of a year ago to meet within their walls, and for the warm welcome with which our coming was greeted on behalf of the city by the Honorable Richard Curran, Mayor of the city of Rochester.

2. To the authorities of the University of Rochester for the free use of the grounds, rooms and facilities of their noble institution of learning throughout the meeting, and particularly to President David J. Hill, for his hearty welcome and constant efforts in our behalf.

3. To the local committee for the many facilities for successful work and agreeable recreation afforded by their liberality and forethought, and particularly to the President, Dr. Edward M. Moore, for his hearty greeting and unflagging courtesy, and to the Local Secretary, Prof. H. Leroy Fairchild, for his untiring and efficient efforts to promote scientific success and bodily comfort.

4. To the Committee on Excursions for their eminently satisfactory arrangements, and to the New York Central and Hudson River Railway Company, the Western New York and Pennsylvania Railway Company, the Delaware, Lackawanna and Western Railway Company, and the Buffalo, Rochester and Pittsburg Railway Company for special trains to Niagara Falls, Canandaigua Lake, Portage and Mount Morris, Stony Brook Glen and the State Fish Hatchery at Mumford; and also to the good people of Canandaigua and Mount Morris for their generous hospitality.

5. To the Ladies' Reception Committee for their constant and eminently successful efforts to render our stay agreeable, for their presence and attention at the general and sectional meetings, and particularly for their courteous and sumptuous reception and for their provision for drives through their beautiful city; also to Mr. D. W. Powers for the use of his splendid Art Gallery for the reception by the Ladies' Committee.

6. To the Young Men's Christian Association for their kindly reception, and particularly for the use of their music hall and rooms for lectures and for this general session.

7. To the Press of Rochester for intelligent and faithful reports of our meetings; to the Railway companies whose lines lead to Rochester from all parts of the land, for highly appreciated concessions; and to the Bell Telephone Company for special facilities and favors; and

8. To the many business establishments of Rochester that have contributed so much toward rendering our visit agreeable and instructive by affording special opportunities for the inspection of interesting processes in applied science, notably the Bausch & Lomb Optical Company, Ward's Natural Science Establishment, the Eastman Kodak Company, and the Ellwanger & Barry Nurseries.

These resolutions were seconded by Mr. Geo. W. Holley, by Prof. O. T. Mason, Prof. S. H. Gage, Rev. H. C. Hovey, Mr. Geo. F. Kunz, Prof. E. W. Claypole, and Prof. T. H. Safford.

Prof. S. A. Lattimore, of the University of Rochester responded on behalf of the Local Committee.

The Local Secretary made the following announcement:

Any members of the Association who would like to visit the salt-shaft at Livonia, which shaft was completed on Friday last, are requested to meet Prof. H. T. Fuller at the Livingston at 9.10 A. M. to-morrow, if the weather is favorable. Free transportation through the courtesy of Superintendent Thompson of the Erie Railway, will be furnished. Train will leave Erie Depot at 9:25 A. M. and return at 5 P. M.

PRESIDENT LECONTE spoke in thanks to both the members of the Association and of the Local Committee, after which he declared the forty-first meeting of the American Association for the Advancement of Science adjourned.

AMOS W. BUTLER, *General Secretary.*

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## REPORT OF THE PERMANENT SECRETARY.

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THE Rochester meeting was the eighth held in the State of New York, and, with the exception of the meeting of 1887, held in New York City, had the largest attendance, notwithstanding the unfortunate railroad strike which caused many members to change their plans and go in other directions, and the long heated term which had driven people to the mountains and sea-shore. In several respects the meeting was a notable one, especially from the number of active workers in science who presented papers and joined in the discussions in the sections. It was also noticeable that the younger members took an active part in the meetings of the sections, which is indicative of the healthy and vigorous condition of the Association.

For several years past the tendency to form societies limited to special branches of science has been regarded by many of the older members of the Association as likely to detract from its meetings. While for a time this seemed possible, it is now considered that the danger is past and that the Association meeting will, in the future, be the nucleus around which all the special societies will gather. In order that this may be done to the best advantage of all concerned, the experiment is to be tried at the meeting of 1893 of beginning the Association meeting with that of the Council on Wednesday, August 16, and having the first General Sessions on Thursday morning, August 17, instead of on Wednesday as heretofore.

The meeting will thus close on the Wednesday night following. Several advantages seem likely to be gained by this change. The sections will organize on Thursday and the Vice Presidents will give their addresses in the afternoon and the Presidential address will be delivered in the evening. Friday will be given entirely to the papers in the sections. Saturday can be taken for excursions; while Monday, Tuesday and Wednesday will be three full days for work in the sections. This will hold the members together to the end of the meeting and there will not be such a breaking up on Saturday as has been the tendency of late years; while those members whose duties will not permit of their remaining a full week will naturally come for the last three days as on those days the most active work in the sections will take place. If a larger number of members is thus secured for the closing days it will certainly add to the dignity of the Association and to its good effect upon the people in whose midst the meeting is held. It is noticeable that the citizens take a more active interest in the proceedings after the first few days of the meeting, particularly after the receptions and excursions have brought them into personal relations with the members, and the work and the objects of the Association have been made known. This is an important consideration in connection with two of the great objects of the Association which are, in the words of the constitution, "to procure for scientific men increased facilities and a wider usefulness" and also "to promote intercourse between those who are cultivating science in different parts of America." Both of these objects are certainly fostered by the social intercourse of the members with each other and with interested and cultured people of each community in which the Association meets, as much as by the formal presentation and discussion of papers. Many persons attending the meetings and becoming acquainted with the workers in science have had their attention for the first time directed in a serious manner to scientific methods and problems and, in consequence, have become earnest promoters of scientific work; while others have been led to take up scientific studies.

A matter of particular note at the Rochester meeting was the discussions following many of the papers read in the sections. These discussions are often of as great importance as the papers upon which they are based, and it seems desirable that arrangements should be made for properly reporting and printing the more important in connection with the abstracts of the papers. It is not to be expected that the secretaries of the sections will be able to make stenographic reports of such discussions, but the question may well be asked if the time has not come when each secretary of a section should have a stenographer by his side who would prepare a report of each day's meeting, which the secretary would revise and prepare for publication in the Proceedings in connection with the papers. This report would increase the value and importance of the proceedings, but it would entail additional work upon the secretaries and would necessitate employing nine stenographers during the meetings of the sections. This would be a considerable expense but the subject is certainly one that should be considered.

For several years the botanists have attended the meetings of the Association in constantly increasing numbers, evidently in large part owing to the activity of the Botanical Club of the Association, and in consequence the number of botanical papers offered in the Biological section has overcrowded that section. This finally led to the demand for a special section for botany and at the Washington meeting a proposition was made to amend the constitution and establish the section. This amendment was adopted at Rochester and *Section G, Botany*, is now fully organized to take effect at the Madison meeting. It henceforward will devolve upon the botanists of the country to sustain the section as they have the Botanical Club and it is to be hoped that the Entomological Club and other zoölogists will be equally active in section F, which is now confined to Zoölogy. As certain papers are of general interest to all naturalists, it is agreed that at least one day at each meeting shall be for a union meeting of the two sections.

The accommodations for the meeting at the University of Rochester were in every way all that could be desired, and to the forethought of the efficient

Local Secretary the Association is greatly indebted for the thorough arrangement made at the University and the many facilities there given to the members. Unfortunately, the accommodations at the hotel headquarters were not as satisfactory as has been the case at most meetings.

The comfortable weather during the meeting was more than was expected after the long heated spell and was a great relief to the members in attendance. The excursions on Saturday and following the meeting were in every way successful and enjoyable.

During the week preceding the Association meeting the several affiliated societies held their meetings and nearly all were well attended.

In the interval between the Washington and Rochester meetings notice of the death of thirty-five members have been received. Among these are two past presidents :—Dr. T. Sterry Hunt who was an original member of the Association and its president in 1870; and Professor Joseph Lovering who joined the Association at its second meeting, 1849; was president in 1873, and for nineteen years, 1854–1872, held the office of Permanent Secretary. This list also includes the names of Professor William P. Trowbridge who was the first Vice-President of Section D, 1882, and of Sir Daniel Wilson who presided as chairman of the then subsection of Anthropology in 1879; also of Dr. Henry I. Bowditch who became a member at the second meeting and was thus among the oldest members of the Association.

The statistics relating to the attendance and the papers presented at the Rochester meeting, which I gave as usual at the closing session, are incorporated in the report of the General Secretary; the following are those relating to membership and to the distribution of the publications.

Of the 175 members elected since the Washington and during the Rochester meeting, 1 has declined membership, 147 have perfected their membership, as have 5 who were elected at the Washington meeting; 7 members have paid their arrears and the assessments of 1 were remitted by the Council, and these have been restored to the roll.

This makes 160 names added to the roll since the Washington volume was published. The name of one corresponding member has been transferred to the list of members.

From the Washington list, 8 names have been transferred to the list of deceased members; 11 members and fellows have resigned and 158 have been omitted for arrearages, making a deduction of 177 from the list.

One member has become a life member and 38 members have been transferred to the roll of fellows.

The following is a comparative statement of the roll as printed in the Indianapolis and Washington volumes and in the present volume:

| | Indianapolis. | Washington. | Rochester. |
|---|---|---|---|
| Patrons, | 3 | 3 | 3 |
| Corresponding members, | 0 | 3 | 2 |
| Members, | 1,185 | 1,269 | 1,246 |
| Honorary fellows, | 2 | 2 | 2 |
| Fellows, | 745 | 777 | 784 |
| | 1,935 | 2,054 | 2,037 |

The distribution of publications since the last report is as follows:

Memoirs No. 1: presented 1 copy. Transactions: sold 1 copy. Proceedings Vols. 1–39: delivered to members, 38; sold 6; exchanges 2; duplicate copies to members 2; bought 1 copy; received as donations 2 copies. Vol. 40: delivered to members 1,651; sold 2; exchanges 241; presented 1; duplicate copies to members 2; returned by exchanges 1; returned by estate of deceased member 1.

| | | |
|---|---|---|
| As stated in the following cash account, the balance on hand at the beginning of the Rochester meeting was - - - - | | $2394.53 |
| The amount of the GENERAL FUND, with interest to Aug. 1, 1892, | | 131.05 |
| The amount of the Research Fund, Aug. 1, 1891 | 5004.27 | |
| Interest to Aug. 1, 1892 - - - - - - - - - | 250.00 | |
| Life memberships added - - - - - - - - - | 150.00 | |
| | 5404.27 | |
| The following grants from the Research Fund were made by the Council of the Rochester meeting:— | | |
| To Prof. Edward Hart for a research on Glucinum, | 100 00 | |
| To Prof. Joseph Jastrow for psychological research, - - - - - - - | 100.00 | |
| To the American Table at Naples Biological Station, provided the additional $400 is raised by the Committee, - - - - - - - - | 100.00 | |
| | 300.00 | |
| | | 5104.27 |
| | | $7629.85 |

F. W. PUTNAM, *Permanent Secretary, A. A. A. S.*

*Salem, Mass., November* 1, 1892.

F. W. PUTNAM, PERMANENT SECRETARY,

Dr. THE AMERICAN ASSOCIATION FOR

| | | |
|---|---|---|
| 1891–92. | | |
| To admission fees Rochester Meeting . . . . . | $125 00 | |
| " " previous to Rochester Meeting . | 940 00 | |
| Fellowship fees . . . . . . . . . . . . . | 114 00 | |
| | | $1,179 00 |
| Assessments previous to Washington Meeting . | 883 00 | |
| " for Washington Meeting . . . . . | 3,978 00 | |
| " for Rochester Meeting . . . . . | 441 00 | |
| Associate fees, Washington meeting . . . . . | 213 00 | |
| | | 5,515 00 |
| Publications sold . . . . . . . . . . . . . | 135 71 | |
| Received for binding . . . . . . . . . . . | 65 70 | |
| | | 201 41 |
| Postage and express charges refunded . . . . | 4 42 | |
| Exchange on checks . . . . . . . . . . . . | 43 | |
| | | 4 85 |
| Life membership commutations . . . . . . . | 150 00 | |
| Income Research fund 1890–91 . . . . . . . | 250 00 | |
| " " " 1891–92 . . . . . . . | 250 00 | |
| | | 650 00 |
| To balance from last account . . . . . . . . | | 1,040 92 |
| | | $8,591 18 |

I have examined the above account and

AUGUST 26, 1892.

IN ACCOUNT WITH

THE ADVANCEMENT OF SCIENCE.

| | | Cr. 1891–92. |
|---|---|---|
| By 2500 copies Proceedings Vol 40 (585 pages) | | |
| Composition and corrections. | $1,221 39 | |
| Illustrations $19.35, special type $17.50 | 36 85 | |
| Electrotyping 80 pages and boxing | 54 45 | |
| Paper $444.00, press work $231.25 | 675 25 | |
| Paper covers and binding 2400 copies | 292 50 | |
| | | $2,280 44 |
| Binding 25 copies Vol. 40, half morocco | 25 00 | |
| " 75 " " " cloth | 37 50 | |
| 25 cloth covers | 5 00 | |
| Printing wrappers and wrapping 2500 copies | 34 50 | |
| 2300 extra copies, addresses and reports | 124 75 | |
| Insurance on volume while printing | 24 50 | |
| | | 251 25 |
| 500 copies constitution and list of members | 42 75 | |
| Printing notices, blanks, cards, paper, etc. | 102 84 | |
| Binding publications | 2 75 | |
| | | 148 34 |
| On account of Vol. 39 of Proceedings 4½ reams paper | 21 00 | |
| Extra copies of address $22.43, electrotyping $1.00 | 23 43 | |
| | | 44 43 |
| 100 extras report Com. Chem. Lit. from Vol 41 | | 3 25 |
| Expenses of Washington meeting | 273 84 | |
| " " Rochester meeting | 15 25 | |
| Express including distribution of Vol. 39 | 342 55 | |
| Postage, stationery, P. O. box rent | 246 79 | |
| Telegrams 94 cts.; stamp $1.00 | 1 94 | |
| Extra clerical services | 28 75 | |
| Subscription to postal guide | 1 50 | |
| Petty expenses | 7 95 | |
| Making shelves for volumes $17.63, boxes $4.35 | 21 98 | |
| Back volumes of proceedings purchased | 6 00 | |
| Assessment refunded (Honorary fellow) | 3 00 | |
| | | 949 55 |
| Expenses of Section I for Washington Meeting | | 61 39 |
| Rent of office to August 1, 1892 | 108 00 | |
| Janitor " " " | 100 00 | |
| | | 208 00 |
| Grant from research fund to Profs. Morley and Rogers | 100 00 | |
| " " " " " Dr. E. Smith | 50 00 | |
| " " " " for American table at Naples | 100 00 | |
| | | 250 00 |
| Carried to Life Membership Fund | | 150 00 |
| Salary of Permanent Secretary to Aug. 1, 1892 | 1,250 00 | |
| " " Assistant Secretary to Aug. 1, 1892 | 600 00 | |
| | | 1,850 00 |
| Balance to new account | | 2,394 58 |
| | | $8,591 18 |

certify that the same is correctly cast and properly vouched.

THOMAS MEEHAN, *Auditor*.

# INDEX.

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