The Administration Building of the Carnegie Institution of Washington

CARNEGIE INSTITUTION

OF

WASHINGTON

YEAR BOOK

No. 8

1909

PUBLISHED BY THE INSTITUTION
WASHINGTON, U. S. A.
FEBRUARY, 1910

WASHINGTON, D. C.
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1910

OFFICERS FOR THE YEAR 1910

President of the Institution

ROBERT S. WOODWARD

Trustees

JOHN S. BILLINGS, *Chairman*
ELIHU ROOT, *Vice-Chairman*
CLEVELAND H. DODGE, *Secretary*

JOHN S. BILLINGS
JOHN L. CADWALADER
CLEVELAND H. DODGE
WILLIAM N. FREW
LYMAN J. GAGE
HENRY L. HIGGINSON
CHARLES L. HUTCHINSON
SETH LOW
S. WEIR MITCHELL
ANDREW J. MONTAGUE
WILLIAM W. MORROW
WILLIAM B. PARSONS
HENRY S. PRITCHETT
ELIHU ROOT
MARTIN A. RYERSON
WILLIAM H. TAFT
CHARLES D. WALCOTT
WILLIAM H. WELCH
ANDREW D. WHITE
GEORGE W. WICKERSHAM
ROBERT S. WOODWARD

Executive Committee

WILLIAM H. WELCH, *Chairman*

*JOHN S. BILLINGS
*CLEVELAND H. DODGE
S. WEIR MITCHELL
WILLIAM B. PARSONS
ELIHU ROOT
CHARLES D. WALCOTT
WILLIAM H. WELCH
*ROBERT S. WOODWARD

Finance Committee

SETH LOW
HENRY S. PRITCHETT
HENRY L. HIGGINSON

* Ex-officio member.

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ARTICLES OF INCORPORATION.

The Carnegie Institution was originally organized under the law governing the organization of corporations in the District of Columbia. Owing to certain limitations in the law, the Trustees deemed it desirable to obtain articles of incorporation from the Congress. Accordingly, articles of incorporation were prepared, submitted to the Congress, amended by the Congress, and enacted into statute by the Congress and the signature of the President.

Organization under the new articles of incorporation was effected on May 18, 1904. Resolutions were passed electing the same Executive Committee and officers as those of the Carnegie Institution organized in 1902 and continuing all instructions and authorizations given to the Executive Committee by the old organization.

PUBLIC No. 260.—An Act To incorporate the Carnegie Institution of Washington.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the persons following, being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

SEC. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees hereinafter appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

SEC. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time

to hold as investments the securities hereinabove referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corporation hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia, January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

SEC. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause

existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

SEC. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

SEC. 9. That this Act shall take effect immediately.

Approved, April 28, 1904.

BY-LAWS OF THE INSTITUTION.

Adopted December 13, 1904.

Article I.

THE TRUSTEES.

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members. The Trustees shall hold office continuously and not for a stated term.

2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.

3. No Trustee shall receive any compensation for his services as such.

4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. No person shall be elected, however, who shall not have been nominated at a preceding annual or special meeting, except by the unanimous consent of the members present at a meeting.

Article II.

MEETINGS.

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the second Tuesday of December in each year.

2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.

3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

Article III.

OFFICERS OF THE BOARD.

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.

2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the

Board and to his duties. He shall execute all deeds, contracts or other instruments on behalf of the corporation, when duly authorized. He shall have custody of the seal of the corporation and shall affix the same whenever authorized to do so by the Board of Trustees or by the Executive Committee or the Finance Committee.

Article IV.

EXECUTIVE ADMINISTRATION.

The President.

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of all property of the Institution whose custody is not otherwise provided for. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

Article V.

COMMITTEES.

1. There shall be the following standing Committees, viz, an Executive Committee and a Finance Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio* and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have general charge of the investments and funds of the corporation, and shall care for and dispose of the same subject to the directions of the Board and of the Executive Committee. It shall consider and recommend to the Board of Trustees such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting.

8. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

Article VI.

FINANCIAL ADMINISTRATION.

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by

a skilled accountant, to be appointed by the Chairman of the Board, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property shall be deposited in such safe deposit or other corporation and under such safeguards as the Trustees and Executive Committee shall designate; and the moneys of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

Article VII.

AMENDMENT OF BY-LAWS.

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

MINUTES

OF THE

Seventh Meeting of the Board of Trustees

DECEMBER 14, 1909.

ABSTRACT OF THE MINUTES OF THE SEVENTH MEETING OF THE BOARD OF TRUSTEES.

The meeting was held in Washington, in the Board Room of the Administration Building, on Tuesday, December 14, 1909, and was called to order at 2 o'clock p. m. by the Chairman, Mr. Billings.

Upon roll-call by the Secretary, the following Trustees responded: John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Henry L. Higginson, Charles L. Hutchinson, Seth Low, S. Weir Mitchell, Andrew J. Montague, William W. Morrow, Wm. Barclay Parsons, Henry S. Pritchett, Elihu Root, Martin A. Ryerson, Charles D. Walcott, William H. Welch, Andrew D. White, Robert S. Woodward.

The minutes of the sixth meeting were approved as printed in abstract and submitted to the Trustees.

The reports of the President, the Executive Committee, the auditor, the Finance Committee, directors of departments, and grantees of the Institution, were presented and considered.

After explanation and discussion, the following general appropriations were made for 1910:

Publication	$50,000
Administration	45,000
Division of Publications	9,000
Departments and large projects	408,661
Minor grants and research associates	89,600
Classics of International Law	15,000
Insurance fund	10,000
	627,261

The resignation of Mr. D. O. Mills was presented and accepted with regret.

The Secretary reported vacancies in the Board of Trustees due to the resignation of Mr. Mills, the death of Mr. Hitchcock, the death of Mr. Lindsay, and the non-acceptance of election by Mr. Eliot.

Mr. William H. Taft was unanimously re-elected a member of the Board.

Mr. George W. Wickersham was unanimously elected to fill the vacancy caused by the resignation of Mr. Mills.

Balloting for officers of the Board for the ensuing three years resulted in the re-election of Mr. Billings as Chairman, Mr. Root as Vice-Chairman, and Mr. Dodge as Secretary.

Messrs. Mitchell, Parsons, and Welch were elected members of the Executive Committee to succeed themselves for a term of three years.

Messrs. Low (Chairman), Pritchett, and Higginson were elected members of the Finance Committee for three years.

The Board adjourned at 4 o'clock and 40 minutes p. m.

Memorial

Carroll Davidson Wright

1840-1909

Carroll Davidson Wright died at his home in Worcester, Mass., February 20, 1909. He was one of the small body of men who gave aid and counsel in inaugurating and maturing the plans of the Institution. He was from the beginning a Trustee and a member of the Executive Committee, serving as Chairman of this Committee from 1904 to 1908, and his experience and advice were of signal service to the Institution. He gave much time and thought to the organization of research work in Economics and Sociology, and when in 1903 the Board of Trustees established a department devoted to these subjects, he was appointed to direct its affairs.

In the early days of the civil war Mr. Wright enlisted as a private in the Fourteenth New Hampshire Volunteers, and he reached the rank of colonel in that regiment. He was a member of the State Senate of Massachusetts in 1872–73, and chief of the Massachusetts Bureau of Statistics of Labor from 1873 to 1878. From 1885 to 1905 he was United States Commissioner of Labor, and during that period he served as a member and recorder of the United States Anthracite Strike Commission and supervised the completion of the Eleventh Census. He was also professor of social economics at the Catholic University of America, professor of statistics and social economics at the Columbian University, and University lecturer on wage statistics at Harvard University. In 1902 he became president of Clark College and remained in that position until his death. His efficient labors in the cause of education, as teacher, lecturer, and administrator were characterized by broad sympathies, sound judgment, and keen appreciation of the developing needs of the generation in which he lived, and all his life work was marked by earnest and unselfish devotion to the highest ideals of citizenship.

Memorial

William Wirt Howe

1833–1909

William Wirt Howe, who was elected a Trustee of the Institution in 1904, died in New Orleans, Louisiana, March 17, 1909.

Mr. Howe was graduated from Hamilton College in 1853. He served in the Union Army during the Civil War, and reached the rank of major. He followed the profession of the law continuously from 1865, and was one of the foremost jurists of the Southern States. He was judge of the chief criminal court of New Orleans, and afterwards became associate justice of the supreme court of Louisiana. Subsequently he twice served as United States District Attorney for the eastern district of Louisiana, receiving an appointment first from President McKinley and then from President Roosevelt.

The engrossing duties of his profession did not limit his intellectual interest and activities. He served as treasurer of the University of Louisiana, president of the Louisiana Historical Society, and president of the New Orleans Civil Service Commission. He was an able lecturer on law and was the author of "Studies in Civil Law" and of the "Municipal History of New Orleans." Although after two years' service as Trustee of the Carnegie Institution of Washington he found it necessary to resign because of pressure of other duties and the distance of his home from Washington, he always manifested warm interest in its work.

Memorial

Ethan Allen Hitchcock

1833-1909

Ethan Allen Hitchcock, who died in Washington, D. C., April 9, 1909, was elected a Trustee of the Institution in November, 1902, to succeed his brother Henry Hitchcock, a member of the original Board of Trustees.

Having attained prominence in commercial life, and a reputation for integrity, high purpose, and industry, he was selected by President McKinley to represent the United States in Russia, as Minister in 1897 and as the first Ambassador to that country in 1898. He was recalled the following year to assume the portfolio of the Secretary of the Interior, which position he held with unusual distinction until his resignation in 1907.

Mr. Hitchcock's wide acquaintance with public affairs and his lively interest in educational matters caused him to take broad views of the needs of the country and of the progress of learning. He was gratified by his election to the Board of Trustees of the Institution, and was in full accord with its purposes, and, although burdened by official cares, he gave much time and thought to its work and progress. By his death the Trustees of the Institution have lost a warm friend and science has lost a powerful ally.

Memorial

William Lindsay

1835–1909

William Lindsay was elected a member of the original Board of Trustees of the Institution on January 4, 1902, and served continuously in that capacity until his death on October 15, 1909, at his home in Frankfort, Kentucky.

Mr. Lindsay began the practice of the law in 1858 and early identified himself with the political history of his country. After the civil war, during which he attained the rank of captain in the Army of the Confederate States, he returned to the practice of his profession. He was twice a member of the State Senate of Kentucky, served as chief justice of the Kentucky Court of Appeals from 1870 to 1878, was elected United States Senator in 1893 to fill the vacancy caused by the resignation of John G. Carlisle, and was re-elected to a full term, remaining in the Senate until 1901. He declined appointment as a member of the Interstate Commerce Commission, tendered by President Cleveland. He was a member of the World's Columbian Commission in 1893 and was a United States Commissioner to the St. Louis Exposition in 1904.

Although Mr. Lindsay was not an active participant in the affairs of the Carnegie Institution of Washington and was unable to attend regularly the meetings of its Trustees, he was ever mindful of its interests and appreciative of the importance of its work, and the Institution has been honored by his membership in its governing body.

REPORT OF THE PRESIDENT

OF THE

CARNEGIE INSTITUTION OF WASHINGTON

FOR THE YEAR ENDING OCTOBER 31, 1909.

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REPORT OF THE PRESIDENT OF THE CARNEGIE INSTITUTION OF WASHINGTON.

In compliance with Article IV of the By-laws of the Carnegie Institution of Washington, I have the honor to submit the following report on the present status of the interests of the Institution and on the events and work thereof for the fiscal year ending October 31, 1909, along with recommendations of appropriations for the ensuing year and with sundry suggestions and recommendations concerning other questions which have been under consideration during the past year.

Explanatory Statement.

This report is the eighth annual report of the Institution and is presented under the following principal heads:

1. Work of administration.
2. Résumé of investigations of the year.
3. Publications.
4. Recommendations of budget for the year 1910.
5. Additional suggestions.

The Institution has lost heavily during the year by deth. Four Trustees, Carroll Davidson Wright, William Wirt Howe, Ethan Allen Hitchcock, and William Lindsay, along with our eminent Research Associate, Professor Simon Newcomb, constitute a noteworthy list of men distinguisht alike for conspicuous public service and for enlightend devotion to the advancement of research and discovery. In accordance with a custom already well establisht, biografys of deceast Trustees are publisht elsewhere in the Year Book, so that further mention of their lives and work need not be made here. It seems fitting, however, in this administrativ report, to recall especially the faithful services renderd by Dr. Wright, who was from the foundation of the Institution a member of the Executiv Committee and its Chairman from December, 1904, to December, 1908. Rarely absent from meetings, always courteous, patient, and helpful, he renderd great aid in forwarding the complex volume of business considerd and disposd of during these years of formativ activity.

Deth Losses of the Year.

Mention may be made here also of the remarkable career of Professor Newcomb, one of the most productiv investigators in the history of American science. Early in life he set for himself the gigantic task of bringing the observd motions of the members of the solar system into harmony with the Newtonian law of attraction, and for nearly fifty years he was one of the small number of leaders in this arduous branch of mathematical astronomy. The harmony in question had been demonstrated to the first order of approximation in that mightiest of all systematic treatises, the Mécanique Céleste of Laplace. But the vast accumulations of precise observations of the planets and their satellites during the nineteenth century showd the necessity for a higher order of approximation, which could be attaind only by an insight and an industry comparable with those of Laplace himself. How well Professor Newcomb succeeded in this great undertaking is attested by the extensiv additions he made to the lunar and the planetary theories and by the universal recognition his work receivd from institutions of learning. He livd a life of indefatigable research, making weighty contributions to almost every field of mathematical and astronomical science. During the long period of his activity he was occupied to an extraordinary degree by the capital gravitational problem presented in the motion of the moon. This motion has baffled the ingenuity of his most eminent predecessors and contemporaries and is not yet fully harmonizd with the Newtonian law. He made great progress, however, in the treatment of this grand problem; and his tenacity of purpose as an investigator is well attested by the fact that his last, as well as his first, more important memoir is devoted to this uniquely difficult subject of research.

Principal Events of Year.

The more important events of the year are the completion of the Administration Building in Washington; the establishment and activ operation of the observatory of the Department of Meridian Astrometry in Argentina; the construction and putting into commission of the non-magnetic ship *Carnegie* of the Department of Terrestrial Magnetism; and the inauguration of the project for the publication of an edition of the master-works on international law. Mention of these will be made in detail in later sections of this report. Attention may be calld here, however, to the fact that with these, and with the previously establisht larger enterprises under way, the accumulated income of the Institution has been exhausted and that there will be no room for further expansion under current income in the immediate future.

Summary of Work of Institution to Date.

In the last annual report a summary statement of the work of the Institution up to October 31, 1908, was given. A more detaild study of the scope and geografic range of this work shows that investigations have been carried on under the auspices of the Institution in more than thirty different fields of research and

that these investigations have extended to more than forty different countries. A map of the world showing the places where work has been done, the routes of surveys, explorations, etc., and the different kinds of work accomplisht will be ready for exhibition at the time of the next meeting of the Trustees. The total number of volumes of publications issued directly by the Institution is 141, with an aggregate of about 35,000 pages of printed matter. For the larger departments of investigation there are now provided two astronomical observatories, five laboratories, and one ship. A complete list of the equipments of these establishments includes 58 buildings and 8 smaller craft in addition to the ship *Carnegie*. The total amount of funds appropriated for expenditure to date is $4,320,140, which includes $307,227.03 which have been reverted and afterwards reappropriated. The total amount expended to date is $4,128,697.11.

Construction and Equipment of Administration Building.

The construction of this building, begun in February, 1908, is now nearly completed, and it has been occupied since the second week in November of this year. Illustrations showing exterior front views and plans showing the interior arrangement of rooms for each of the three floors will be reproduced in the forthcoming Year Book. It may suffice here, therefore, to state that this building is admirably well adapted to its purposes and that its construction has been exceptionally well carried out by the contractors, Messrs. J. E. and A. L. Pennock, of Philadelphia, Pennsylvania.

The most important items of equipment for this building are lighting fixtures, furniture, and fireproof shelving for books and manuscripts. Complete data for the costs of equipment are not yet available. It may be stated, however, that the total cost of the building and its equipment will fall within the limits of the building fund.

Astronomical Observatory in Southern Hemisphere.

At the date of the preceding annual report the Department of Meridian Astrometry was engaged in the construction of a temporary observatory at San Luis, Argentina. The instrumental equipment for this was shipt from the Dudley Observatory, Albany, N. Y., in December, 1908. After safe transportation to San Luis, the constants of the meridian transit, the principal instrument used, were carefully redetermind, proving to the highest order of precision that this instrument sufferd no injury in transshipment. With this indispensable preliminary investigation completed, the work of stellar observation was begun in April, 1909, and is now going on at a rate surpassing any hitherto attaind in this branch of astronomy.

Following up the approval by the Board of Trustees at their meeting of December, 1908, of the recommendations of the Executiv Committee with respect to a specially designd ship for ocean magnetic work, a contract for her construction was let on December 9, 1908, to the Tebo Yacht Basin Co., of Brooklyn, N. Y., for the sum of $100,935. She was launcht June 12, 1909, and started on her trial voyage August 21, 1909. She proceeded first by Long Island Sound to Gardiner's Bay, Long Island, where she was swung repeatedly to test her magnetic properties. Thence she said to St. Johns, Newfoundland; thence to Falmouth, England; and she is now engaged in a magnetic survey of the Atlantic. Further reference will be made to this novel ship in a subsequent section of this report.

The Non-magnetic Ship Carnegie.

In conformity with the vote of the Trustees at their last meeting, steps were taken early in the year to carry out the project of publishing an edition of the early masterpieces in international law, suggested to the Institution by Professor James Brown Scott in 1906. The proposal of Professor Scott to act, without pecuniary compensation, as general editor of the series was accepted by the Executiv Committee at its meeting of March 9, 1909, and the project is now well under way. In accordance with the plan submitted a year ago, each work is to be reproduced by fotografic process from the best available edition (usually in Latin), each is to be accompanied by a complete translation into English, with an introductory commentary prepard by an expert specially qualified to interpret the work. The merits of this enterprise have enlisted the cooperation of eminent authorities in international law. Thus, of the works already begun, Professor Westlake, of the University of Cambridge, will furnish a commentary for the work of Ayala; Professor Holland, of the University of Oxford, will furnish commentaries for the works of Zouche and Gentilis; while Professor Scott will perform a similar office for the works of Grotius. It is expected that copies of the fotografic reproduction of the "Juris et judicii fecialis, sive juris inter gentes" of Zouche and the "De jure belli ac pacis" of Grotius will be ready for inspection at the time of the coming meeting of the Trustees.

Classics of International Law.

From the foundation of the Institution it was recognizd that the issue of publications would become one of its most important functions. Naturally enough the details of the earlier work in this line were divided between the officers of administration and the authors of the publications issued under the auspices of the Institution. As the work developt the need of expert editorial supervision led to the employment for this purpose of Mr. William Barnum, who has

Establishment of Division of Publications.

been Editor since January, 1904. Serving the Institution also as Chief Clerk since that date, his salary and parts of other expenses incidental to his editorial work have been charged to the cost of administration. This inconsistency of charge having been pointed out repeatedly by the President and by our auditors, the Executiv Committee at its meeting of May 12, 1909, authorizd the establishment of a Division of Publications with Mr. Barnum as Editor in Charge. By this formality, what was already virtual is renderd actual and a better distribution of labor and cost charge is secured. With the transfer to the new administration quarters, the office of Chief Clerk will lapse and the duties of this office will be assumd by Mr. W. M. Gilbert, Assistant Secretary of the Institution.

Financial Statement for the Fiscal Year 1908–1909.

The sources of funds available for expenditure during the past year, the allotments for the year, and the balances unallotted at the end of the year are shown in detail in the following tabular statement:

	Unallotted Oct. 31, 1908.	Appropriation, Dec. 8, 1908.	Revertments Oct. 31, 1908, to Oct. 31, 1909.	Total.	Aggregates of allotments and amounts transferred.	Balances unallotted Oct. 31, 1909.
Large grants	$27,500.00	$435,500	$4,500.00	$467,500.00	$467,500.00	.....
Minor grants	.....	45,800	5,169.32	50,969.32	49,969.32	$1,000.00
Research associates and assistants	.....	30,000	575.02	30,575.02	30,575.02	.....
Publications	14,698.01	60,000	7,141.79	81,839.80	54,645.27	27,194.53
Administration	12,915.70	50,000	294.27	63,209.97	49,792.21	13,417.76
Total	55,113.71	621,300	17,680.40	694,094.11	652,481.82	41,612.29

The following list shows the departments of investigation to which the larger grants were made by the Trustees and the amounts allotted from those grants by the Executiv Committee during the year:

Department of Botanical Research	$32,000
Department of Economics and Sociology	17,500
Department of Experimental Evolution	29,000
Department of Historical Research	20,500
Department of Marine Biology	15,000
Department of Meridian Astrometry	30,000
Department of Terrestrial Magnetism	60,000
Department of Terrestrial Magnetism, vessel	75,000
Geophysical Laboratory	45,000
Horticultural work of Luther Burbank	10,000
Nutrition Laboratory	25,000
Solar Observatory	104,000
Division of Publications	4,500
	467,500

The fields of investigation to which minor grants were assigned, the names of the grantees, and amounts of the grants are shown in the following list:

Details of minor grants.

Field of investigation.	Names of grantees.	Amount of grants.
Archeology	American School of Classical Studies at Athens	$2,500.00
	American School of Classical Studies in Rome	1,600.00
Astronomy	Newcomb, Simon	5,000.00
	Gale, Henry G	500.00
Bibliografy	Index Medicus	12,500.00
Botany	Cowles, Henry C	500.00
Chemistry	Bancroft, W. D	1,500.00
	Jones, H. C	1,200.00
	Acree, S. F	1,300.00
	Baxter, G. P	1,000.00
	Smith, Edgar F	2,000.00
Mathematics	Morley, Frank	1,000.00
Meteorology	Bjerknes, V	1,200.00
Paleontology	Wieland, G. R	2,000.00
	Case, E. C	1,600.00
Physics	Burgess, C. F	2,500.00
	Howe, Henry M	500.00
Zoology	Naples Zoological Station	1,000.00
	Mark, E. L	100.00
	Castle, W. E	1,000.00
	Crampton, H. E	2,500.00
		43,000.00
Unallotted balance transferd to unappropriated fund		6,969.32
		49,969.32

The following table shows the fields of investigation of research associates and the amounts of their grants:

Field of investigation.	Names of research associates.	Amount of grants.
Astronomy	Kapteyn, J. C	$1,800.00
	Nichols, Ernest F	1,000.00
	Gale, H. G	1,000.00
Archeology	Van Deman, E. B	1,000.00
Botany	Account of the work of Luther Burbank	600.00
Chemistry	Richards, Theodore W	2 500.00
	Morse, H. N	1,800.00
Geology	Chamberlin, T. C	4,000.00
	Moulton, F. R	2,000.00
Geophysics	Ludwig, Albert	,500.00
Nutrition	Osborne, Thomas B	5,000.00
Physics	Barus, Carl	500.00
	Nichols, E. L	3,000.00
	Noyes, A. A	3,000.00
Physiology	Loeb, Leo	500.00
Political Science	Rowe, L. S	1,500.00
		29,700.00
Unallotted balance transferd to unappropriated fund		875.02
		30,575.02

The following grants for publication were authorized during the year:

Barus, Carl	$700.00
Benedict, F. G., and T. M. Carpenter	700.00
Boss, Lewis	3,000.00
California State Earthquake Commission	2,862.90
Cannon, W. A.	1,000.00
Carnegie Institution of Washington	500.00
Castle, W. E.	619.37
Chamberlin, T. C., *et al.*	574.72
Coblentz, W. W.	238.02
Davenport, C. B.	2,100.00
Decker, Floyd F.	400.00
Hay, O. P.	147.94
Index to Public State Documents	10,000.00
Jones, H. C., and J. A. Anderson	$558.56
Johnson, R.	800.00
Mayer, A. G.	3,400.00
Muller, W. Max	3,400.00
Perrine, Charles D.	900.00
Pumpelly, R.	2,402.21
Reichert and Brown	6,000.00
Republication of Classics of International Law	10,000.00
Richards, Wilson, and Garrod-Thomas	450.00
Robertson, J. A.	1,600.00
Sommer, H. O.	2,000.00
Van Deman, Esther B.	91.55
Wieland, G. R.	200.00
	54,645.27

The sources and amounts of the revertments from November 1, 1908, to October 31, 1909, inclusiv, are as follows:

Large Grants:		
Transferred from Administration		$4,500.00
Minor Grants:		
Pumpelly, R., Grant No. 229	$1,124.64	
Kunz, G. F., Grant No. 52	500.00	
Becker, G. F., Grant No. 423	.31	
Carnegie Institution of Washington, Grant No. 457	1,500.00	
Newcomb, Simon, Grant No. 550	2,044.37	
		5,169.32
Research Associates and Assistants:		
Nichols, Ernest F., Grant No. 568	500.02	
Goldthwait, J. E., Grant No. 469	75.00	
		575.02
Publication:		
Barus, Carl, Grant No. 510	512.27	
Cannon and Knox, Grants Nos. 507–508	349.34	
Chamberlin, R. T., Grant No. 521	190.80	
Hale and Fox, Grant No. 471	33.03	
Andrews and Davenport, Grant No. 464	1,383.12	
Chamberlin, T. C., *et al.*, Grant No. 526	57.30	
Pumpelly, R., Grant No. 388	518.00	
Castle, W. E., Grant No. 536	18.46	
Papers of Marine Biological Laboratory, Grant No. 527	585.17	
Eigenmann, C. H., Grant No. 518	1,961.77	
Shull, G. H., Grant No. 523	381.39	
Richards, T. W., *et al.*, Grant No. 584	98.47	
Cannon, W. A., Grant No. 580	459.68	
Flexner and Noguchi, Grant No. 92	592.99	
		7,141.79
Administration:		
Expressage	18.55	
Printing	273.28	
Customs duty	2.44	
		294.27
		17,680.40

Summary of Receipts and Expenditures of the Institution to Date.

The aggregate receipts from interest on endowment, from interest on bond investments, from interest on deposits in banks, from sales of publications, from refund on grants and miscellaneous items to date is $4,246,875.68, as shown by the following table:

Year ending Oct. 31—	Interest.		Sales of publications.	Refund on grants.	Miscellaneous items.	Total.
	Endowment.	Bonds and bank deposits.				
1902.....	$250,000.00	$9.70	.....	.....	$1,825.52	$251,835.22
1903.....	500,000.00	5,867.10	$2,286.16	.....	101.57	508,254.83
1904.....	500,000.00	33,004.26	2,436.07	$329.33	669 70	536,439.36
1905.....	500,000.00	25,698.59	3,038.95	200.94	150.00	529,088.48
1906.....	500,000.00	27,304.47	4,349.68	2,395.25	19.44	534,068.84
1907.....	500,000.00	22,934.05	6,026.10	2,708.56	15.22	531,683.93
1908.....	550,000.00	17,761.55	7,877.51	25.68	48,034.14	623,698.88
1909.....	600,000.00	14,707.67	11,182.07	2,351.48	103,564.92	731,806.14
	3,900,000.00	147,287.39	37,196.54	8,011.24	*154,380.51	4,246,875.68

*Includes $150,750.00 received from sale of bonds.

The purposes for which funds have been appropriated by the Board of Trustees of the Institution may be summarily classified under five heads, namely: (1) investments in bonds and on account of Administration Building; (2) large projects; (3) minor projects, special projects, and research associates and assistants; (4) publications; (5) administration. The actual expenditures under these heads for each year since the foundation of the Institution are shown in the following table:

Year ending Oct. 31—	Investments in bonds and on account of administration building.	Large projects.	Minor projects, special projects, research associates and assistants.	Publications.	Administration.	Total.
1902.....	.....	.....	$4,500.00	.....	$27,513.00	$32,013.00
1903.....	$100,475.00	.....	137,564.17	$938.53	43,627.66	282,605.36
1904.....	*196,159.72	$49,848.46	217,383.73	11,590.82	36,967.15	511,949.88
1905....	51,937.50	269,940.79	149,843.55	21,822.97	37,208.92	530,753.73
1906.....	63,015.09	381,972.37	93,176.26	42,431.19	42,621.89	623,216.80
1907.....	2,000.00	500,548.58	90,176.14	63,804.42	46,005.25	702,534.39
1908.....	68,209.80	448,404.65	61,282.11	49,991.55	48,274.90	676,163.01
1909.....	116,756.26	495,021.30	70,813.69	41,577.48	45,292.21	769,460.94
Total..	598,553.37	2,145,736.15	824,739.65	232,156.96	327,510.98	4,128,697.11

*This amount includes an investment of $94,722.22 of the surplus cash account in bonds, as follows:
$50,000 Northern Pacific-Great Northern 4 per cent joint bonds, Chicago, Burlington and Quincy collateral, July, 1921.
$50,000 Lake Shore and Michigan Southern Railway 4 per cent debenture bonds.

On account of site for and construction of the Administration Building of the Institution, and on account of real estate, buildings, and equipments of departmental establishments, the following sums have been expended:

Administration:		
Building and site (chargeable to Administration Building Fund)	$249,981.15	
Furniture	4,437.63	
		$254,418.78
Publications:		
Stock on hand and outstanding accounts		126,648.92
Department of Botanical Research (September 30, 1909):		
Buildings, office, and library	22,880.53	
Apparatus	5,701.00	
Operating appliances	6,124.58	
		34,706.11
Department of Experimental Evolution (September 30, 1909):		
Buildings, office, and library	36,339.58	
Laboratory apparatus	2,586.49	
Field appliances	7,079.79	
		46,005.86
Geophysical Laboratory (September 30, 1909):		
Building, library, operating appliances	107,874.22	
Laboratory apparatus	55,087.06	
Shop	10,262.07	
		173,223.35
Department of Marine Biology (September 30, 1909):		
Vessels	12,712.55	
Buildings, docks, furniture, and library	9,311.83	
Apparatus	1,320.02	
		23,344.40
Department of Meridian Astrometry (June 30, 1909):		
Buildings and operating appliances	13,507.94	
Apparatus	2,090.94	
		15,598.88
Nutrition Laboratory (September 30, 1909):		
Building and office	106,861.03	
Laboratory apparatus	8,577.73	
Shop	1,592.21	
		117,030.97
Solar Observatory (August 31, 1909):		
Buildings, grounds, road, and telephone line	103,325.76	
Shop	17,012.63	
Instruments	222,241.97	
Furniture and operative appliances	33,505.02	
Hooker telescope	27,525.93	
		403,611.31
Department of Terrestrial Magnetism (September 30, 1909):		
Office	3,934.40	
Instruments	22,899.22	
Vessel and ocean equipment	111,512.11	
Land equipment	614.74	
		138,960.47
		1,333,549.05

RÉSUMÉ OF INVESTIGATIONS OF YEAR.

Status of Departmental Affairs.

For convenience of reference the designations of the ten larger departments of research now maintaind by the Institution and the names of their directors may be here cited:

1. Botanical Research: D. T. MacDougal, Director.
2. Economics and Sociology: Henry W. Farnam, Chairman.
3. Experimental Evolution: Charles B. Davenport, Director.
4. Geophysical Research: Arthur L. Day, Director.
5. Historical Research: J. F. Jameson, Director.
6. Marine Biology: Alfred G. Mayer, Director.
7. Meridian Astrometry: Lewis Boss, Director.
8. Research in Nutrition: Francis G. Benedict, Director.
9. Solar Research: George E. Hale, Director.
10. Terrestrial Magnetism: L. A. Bauer, Director.

As indicated in the report of a year ago, the expanding needs of these departments in the face of adverse economic conditions must soon press closely upon the income of the Institution. Prices of commodities and the cost of living have risen continuously during the past decade and there seems to be adequate reason to anticipate that both will go still higher in the immediate future. This is a world-wide phenomenon, affecting adversely all institutions sustaind by fixt incomes. Its effect on the departments is offset to some extent by their increast efficiency derivd from the experience preliminary to novel enterprises. But this efficiency is in turn counterbalanced temporarily by the further cost entaild by perfected methods and equipments whose adoption is justified by their greater productivity. Hence, while practicing the strictest economy, the departments must be prepard, if necessary, to curtail the quantity of research in order to maintain the highest standards in the quality of the work undertaken.

It may be noted with approval that several of the younger men of markt abilities in the staffs of the departments have resignd during the year to take up work in academic institutions. This early recognition of the merits of men traind in the departments is perhaps the best indication of the relation the Institution should sustain to colleges and universities.

The departments generally are proving increasingly productiv in work accomplisht and increasingly fertile in resources essential to the researches they have under way. Thus their efficiency, whether it be measured by results already publisht or by results anticipated, conforms with the standards of scientific investigation.

Altho most of the departments are still to some extent in the formativ stages, the trend of development is in every case now evident. Each occupies a distinct field and each has attackt problems whose solution is not likely to be undertaken by other organizations. Their ultimate success will depend

in the main on concentration of effort and persistence of industry, along with ample financial and patient moral support from the Board of Trustees.

In anticipation of the retrospectiv view which will be naturally taken at the forthcoming meeting of the Board of Trustees, the heads of departments have been invited by the Executiv Committee to place on exhibition in the new Administration Building such evidences of their work and results already attaind as may be readily available. It is hoped that the Trustees may thus become more intimately acquainted with the general features if not with the complex details of departmental researches. In view of this proposed exhibition and in view of the admirable summaries in the current departmental reports of work completed and of work in progress, the following references to the several departments are restricted to narrow limits.

Department of Botanical Research.

The growing public appreciation of the research work to which the Institution is devoted is manifested in many ways. Thus when a few years ago some members of the staff of the Desert Botanical Laboratory transferd their investigations during the hotter part of the year from Tucson, Arizona, to Carmel, California, on the Pacific Coast, the Carmel Development Company offerd to supply them with a laboratory and grounds suitable for the conduct of their studies and experiments. This offer was accepted by the Board of Trustees at their meeting of December 8, 1908, and during the past summer the department has made use of the building and grounds so generously placed at its disposal. A picture of this building will be shown in the forthcoming Year Book. In addition to the excellent facilities of the laboratory, the grounds afford increast opportunities to study the effects of transfers of plants from the conditions of one environment to those of another.

The various investigations of the department, hitherto outlined, have been successfully continued during the past year. Among these the experiments of the Director in the production of mutants in plants seem destined to play a fundamental role in the determination of the absorbing biological question of the derivation of species. Equally important in this same line are the experiments with beetles of Professor Tower, for whom vivaria are now maintaind at the Desert Laboratory at Tucson and at the Marine Biological Laboratory at Dry Tortugas, Florida.

Dr. B. E. Livingston severd his connection with the department on October 1, 1909, in order to accept a professorship in Johns Hopkins University. The Department will lose also, at the end of the calendar year, the activ services of Professor Volney M. Spalding, who will retire at that time under the terms of the Carnegie Foundation for the Advancement of Teaching.

It is an interesting fact that while biology is one of the most recent and most recondite of the sciences, the rapidity of its development is unparalleld.

Department of Experimental Evolution.

It dates essentially from the epoch of publication of Darwin's Origin of Species in 1859. Herbert Spencer asserts that at the time of the issue of his work on biology (1864) "not one person in ten or more knew the meaning of the word . . . and among those who knew it, few cared to know anything about the subject." It is interesting to note also that we are now witnessing the passage of biological science from the qualitativ to the quantitativ stage. Thus the work of the Department of Experimental Evolution presents a double interest in furnishing evidences at once of the evolution of organic forms and of the evolution of a science. The history of biological science, like the history of most sciences in their earlier stages, has been, and still is, mard to some extent by heated controversy. But all this is destind to disappear with the rise of biology to the plane of quantitativ determination. It is on this plane that the department in question is seeking, with capital initial success, to carry on its investigations. The publications of the department already issued are reckond among the most important of recent contributions in this large field of research.

Dr. George H. Shull, of the departmental staff, has continued his studies of the plant developments of Luther Burbank with the expectation of completing this work by the end of the calendar year.

The facilities of the department have been increast during the year by the purchase of Goose Island, in Long Island Sound, for the purpose of providing an area where the development of plants and animals in a state of isolation may be observd.

This department was establisht in the early part of 1904 in accordance with a resolution past by the Executiv Committee on January 19, 1904. Dr.

Department of Economics and Sociology.

Carroll D. Wright, then a Trustee and a member of the Executiv Committee, was given general supervision of the project as director of the department. The field of investigation was divided originally into eleven sections, to which another was added in 1906. Dr. Wright assumd the work of one of these sections himself, and assignd the work of the other eleven sections, respectivly, to as many collaborators, a majority of whom are connected with colleges and universities, and all of whom are preoccupied with other duties.

Soon after the death of Dr. Wright the collaborators were invited to meet the President for conference with reference to the existing status and the future conduct of the work of the department. Such a conference was held in the office of the Institution at Washington, March 20, 1909. In addition to full reports renderd at this time, the details of which need not be given

here, the collaborators recommended that Prof. Henry W. Farnam, of Yale University, who has hitherto acted as secretary of the collaborators, be made chairman of the department. This recommendation was approvd by the Executiv Committee at its meeting of April 19, 1909, and Professor Farnam immediately assumd the duties of the position.

At the meeting just mentiond Professor Farnam was requested to furnish, for the advice of the Executiv Committee, certain special and general reports, which are now available, concerning the work of the department and its probable future needs. But since the details of these matters are yet to be considerd by the Executiv Committee and by the Board of Trustees, further reference to them would be premature here.

As to the progress of the work of the department during the year, attention is invited to the full and clear report of Chairman Farnam in the forthcoming Year Book.

Thus far the only publications of the department issued by the Institution directly are the Indexes of Economic Material in the Documents of the States of the United States. These have been prepard under the direction of the department by Miss Adelaide R. Hasse, of the New York Public Library. Eight volumes for the States of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, New York, California, and Illinois, respectivly, have appeard and a volume for Kentucky is now in press.

Department of Historical Research.

Probably no department of research under the auspices of the Institution is in close contact with so many scholars as the Department of Historical Research. Its work appeals not only to a large professional class, but also to the reading and reflecting public at large. Hence the indirect advantages arising from the stimulus to individual historical investigation generated by the work of the department are already widely diffused and appreciated.

Search for the sources of American history has been vigorously carried forward during the year in the United States, Great Britain, France, Germany, Italy, and Mexico. The comprehensiv "Guide to the Manuscript Materials for the History of the United States to 1783 in the British Museum, in Minor London Archives, and in the Libraries of Oxford and Cambridge" has been issued as Publication No. 90 during the year, and similar guides are in press or in preparation therefor. The mass of materials thus renderd available to the historian, the economist, the sociologist, and the statesman should help much to place American history on a higher plane than any hitherto attainable.

The attention of the Trustees is invited to the interesting and instructiv full report of the Director in the current Year Book, and especially to his

recommendations with respect to a project for the publication at some future time of an atlas of historical geography of America, for the preliminary consideration of which a small appropriation is approvd for the budget of 1910.

The Geophysical Laboratory.

The work of this laboratory proceeds by means of some of the most recent methods and appliances of research, and hence its aims and lines of investigation, like those of all new sciences, present to the public more or less of obscurities of interpretation and obstacles to ready appreciation. The Director has therefore properly taken occasion in his report for the year to furnish additional explanations of the nature and the scope of his enterprise. Referring to his report for instructiv details, it may suffice here to state that the researches of the laboratory afford another instance of the normal evolution of a science from the observational and descriptiv stage to the higher level of measurement and calculation. That geology and mineralogy will be much advanced by such researches is now recognized and attested by eminent specialists. Indeed, the definitiv results already attaind by members of the laboratory staff are now finding their way into the elementary as well as into the more technical literature of those sciences.

Many publications have been issued during the year by members of the laboratory staff, chiefly thru current journals, which provide easier access for contributions to mineralogy and geology than to most other sciences.

The equipment of the laboratory has receivd an important addition during the year in apparatus for subjecting materials under observation to high pressures and high temperatures, either simultaneously or separately. This apparatus, developt by Dr. A. Ludwig, Research Associate of the department for the year, will give pressures up to 17,000 atmospheres, or 250,000 pounds per square inch.

Department of Marine Biology.

The Tortugas laboratory of this department is proving highly effectiv as a center for research by a wide range of specialists. Eight associate investigators have availd themselves of the opportunities afforded by the department during the past season; and the results of their studies are now in preparation for publication as contributions to science from the laboratory. Two important volumes of such contributions have been issued as Nos. 102 and 103 of the publications of the Institution during the year.

A comprehensiv résumé of the work of the department up to date is given by the Director in his current report, and attention is specially invited to the succinct and clear exposition he gives of the results attaind at the laboratory by himself and by his associates. It is of interest to note the advent of quan-

titativ investigations here as well as elsewhere in the advancing biological sciences.

The Director's work on the second and third volumes of "The Medusæ of the World" is also progressing favorably; while the first volume, now in press as publication No. 109, is well advanced.

Department of Meridian Astrometry.

As already indicated in a preceding section of this report, the arduous enterprise of building, equipping and putting into activ operation an observatory for determining positions of stars in the southern hemisphere has been successfully carried out during the year. This work has been accomplisht in the face of many difficulties, not the least of which has been the world advance in costs of commodities, construction, transportation, and living expenses. This advance has been from 20 to 50 per cent since the estimates for this project were drawn up five years ago. In spite of these difficulties, however, the definitiv program of measurements at the observatory was begun in April, 1909, and is now proceeding with unequald efficiency.

Simultaneously also with the establishment of the observatory in Argentina, work on the general project of the department, namely, the production of a catalog giving precise positions of all stars from the brightest down to those of the seventh magnitude inclusiv (about 25,000 in number), has been continued at the Dudley Observatory.

The Director's "Preliminary General Catalogue of 6188 Stars for the Epoch 1900, including those Visible to the Naked Eye and Other Well Determined Stars," now in press, is nearly ready for issue as Publication No. 115 of the Institution. The demand for this catalog shows that it will take at once a fundamental place as an authority in positional astronomy.

The Nutrition Laboratory.

At the beginning of the present calendar year the equipment of this novel establishment was so far advanced that work of experimentation was activly begun. The apparatus of the laboratory proves highly effectiv, and the experiments already made, on pathological as well as normal subjects, fully justify the confident expectations hitherto entertaind with respect to this line of research. For necessarily technical details with regard to these experiments reference must be made to the Director's report and to publications emanating from the laboratory staff.

Many additions have been made during the year to the equipment of the laboratory. Among these are a bed-calorimeter into which a recumbent patient may enter with ease and safety; a portable respiration apparatus which may be applied readily to a patient reclining on a cot while his respira-

tory action is accurately determind; and an automatic temperature register which will give a continuous record of temperature changes in the calorimeters to which it is applied.

Along with the work carried on at the new laboratory, computations of additional results of experiments, previously executed in the laboratory of Wesleyan University, have been continued. A volume giving an account of these experiments on respiratory exchange and energy transformation in man is now in press as publication No. 123. In connection with these earlier researches, it has been shown, among other interesting facts, that in muscular work man attains about the same mechanical efficiency as the recently developt internal-combustion engine.

The achievments already attaind in the development of novel methods and effectiv apparatus for studies of the sun, and the additions to our knowledge of solar physics already made at this observatory, not only justify the predictions of its founders but warrant the anticipation of still more important contributions to astrophysics in the near future. Work of investigation and work of construction have proceeded simultaneously during the year, both at the observatory site on Mount Wilson and at the shops and physical laboratory in Pasadena.

The Solar Observatory.

The 60-inch equatorial reflecting telescope, whose installation was completed a year ago, has been tested during the past year and proved to be of unequald excellence, whether used as a visual or as a fotografic instrument. Its optical perfection and its wide range of applicability make it a noteworthy contribution to progress in observational astronomy. The 150-foot tower telescope, authorizd by the budget of the current year, is in a forward state of construction and will soon become one of the most effectiv units in the telescope battery of the observatory.

The capital discovery of the existence of the Zeeman effect in the sun, announced by the Director a year and a half ago, has been confirmd and extended in its application to further interpretation of the nature of sunspots, as well as to researches into the more recondite electromagnetic properties shown by the sun. Closely connected, apparently, with these properties are the major and minor "magnetic storms" to which the earth's magnetism is subject, now of special interest alike to the staff of the Solar Observatory and to the staff of the Department of Terrestrial Magnetism. Approaching the observd phenomena from different points of view, the cooperation of these two departments can hardly fail to secure distinct advances in this fruitful field of research. Indeed, in general, the work of the Solar Observatory may be considerd as important to terrestrial physics as it is to solar physics.

The report of the Director gives a summary of the more important results accomplisht to date in his studies of the sun, an account of the experiments

which demonstrate the high efficiency of the 60-inch equatorial telescope, and many other interesting details concerning the progress of his department of work; to all of which the attention of the Trustees is respectfully invited. It may suffice here, therefore, to record only one other item of interest, namely, the failure thus far of the manufacturers of glass at St. Gobain, France, to furnish a satisfactory disk for the 100-inch Hooker telescope. The disk reported as en route for delivery a year ago proved so defective that it had to be rejected. The distinguisht manufacturers are still confident, however, that they can meet the requirements, and it is hoped that thru the collaboration of Professor Ritchey, of the Observatory staff, who has spent some months at St. Gobain during the year, a satisfactory disk may be ultimately secured.

Department of Terrestrial Magnetism.

The most important event of the year in connection with this department is the construction, equipment, and putting into commission of the non-magnetic ship, registerd as the yacht *Carnegie*. A contract for the construction of this ship was let on December 9, 1908, to the Tebo Yacht Basin Company, of Brooklyn, N. Y. She was launcht on June 12, 1909, and set sail on her trial voyage August 21, 1909. She is primarily a sailing craft of brigantine rig, but is provided also with auxiliary propulsion by means of an internal-combustion engine for which gas is supplied by a producer which will generate gas from coal, lignite, or wood.

The *Carnegie* sailed first to Gardiner's Bay, Long Island, thence to St. Johns, Newfoundland, thence to St. Johns, Newfoundland, and thence to Falmouth, England. She will continue magnetic surveys of the Atlantic until about the first of February, 1910, when she will return to Brooklyn to have copper sheathing applied to her hull.

Altho it is now too early to report adequately with respect to the performance of this unique ship, it may be said that she is highly satisfactory in all essential particulars. She proves to be so nearly non-magnetic that corrections for her magnetism are of the same order as the errors of observation to which magnetic determinations are subject. In this fundamental property she quite outclasses the yacht *Galilee,* charterd during 1905 to 1908 for magnetic surveys of the Pacific Ocean. It may be stated also that in her first voyage across the Atlantic errors of prime importance to navigation were found in the best magnetic charts now used by mariners.

It is a source of pleasure to record the fine scientific spirit of cooperation shown by all parties connected with the design, construction, and use of this vessel. The Institution is especially indebted to the high professional skill and fidelity of Mr. Henry Gielow, architect and superintendent, and to Mr.

Wallace Downey, chief constructor, of the ship. They spard no pains to make her come up to her novel and exacting requirements.

The field-work of the department has gone forward also with corresponding dispatch. Surveys have been carried on in fifteen different countries distributed over four different continents. The routes traverst by the observers will give a large aggregate of data from hitherto little-known or unexplord regions. Thus, Mr. Sowers has obtaind observations at intervals along a route extending from eastern China west across China and Chinese Turkestan, and thence south to Bombay, India; Professor Beattie, Research Associate of the Department, is now near Khartoum en route from Cape Town to Cairo; Mr. Pearson has secured measurements in Persia, Beluchistan, Arabia, Turkey, and Russia; while other observers have been equally active in South America, Central America, and British America.

In the meantime the office computations of the results from the surveys of the *Galilee* on the Pacific Ocean, along with similar computations from field observations, are approaching the publication stage. The office staff is also continuously occupied with the work of comparison, testing, repairs, and construction of instruments along with many researches into the numerous manifestations and the possible cosmic connections of terrestrial magnetism. For details with respect to these more technical matters reference may be made to the Director's annual report and to the departmental publications of the year.

Investigations of Research Associates.

Many capital researches have been carried on during the year by eminent associates of the Institution. Fifteen of these have been connected directly with the several departments concerned, thirty of them have pursued their investigations independently, while four have been enlisted in the enterprise for the publication of an edition of the master-works on international law. Reports of progress from many of these associates will be found in the current Year Book, and lists of their publications are included, so far as obtainable, in the bibliografy for the year. The range of these investigations extends to fifteen distinct fields, namely: archeology, astronomy, astrophysics, chemistry, cosmogony, geology, geophysics, international law, literature, mathematics, metallurgy. meteorology, paleontology, physics, and zoology.

PUBLICATIONS.

Publications Authorized and Issued during the Year.

The publication of 16 volumes of researches has been authorized by the Executiv Committee during the year at an aggregate estimated cost of $29,200. The following list gives the titles and authors of the publications issued during the year. It includes 19 volumes, with an aggregate of 3,695 octavo pages and 1,212 quarto pages.

List of publications issued during the year.

Year Book, No. 7, 1908. Octavo, VII + 240 pages, 12 plates.
Index Medicus, Second Series, vol. 6, 1908. Octavo, 1,189 pages.
No. 73. Pumpelly, Raphael, *et al.* Explorations in Turkestan, expedition of 1904. Prehistoric Civilizations of Anau. In two volumes. Quarto.
Volume 2. Reports by R. W. Pumpelly and J. U. Duerst, with contributions by G. Sergi, Th. Mollison, H. C. Schellenberg, and Langdon Warner. Pages x + 241–494 + x, plates 61–97, and text figures 431–548.
No. 85. Hasse, Adelaide R. Index of Economic Material in the Documents of the States of the United States. Prepard for and under the direction of the Department of Economics and Sociology of the Carnegie Institution of Washington. Separate volume for each State. Quarto. California (1849–1904), 316 pages. Illinois (1809–1904), 393 pages.
No. 90. Andrews, Charles M., and Frances G. Davenport. Guide to the Manuscript Materials for the History of the United States to 1783 in the British Museum, in Minor London Archives, and in the Libraries of Oxford and Cambridge. Octavo, XIV + 499 pages.
No. 97. Coblentz, W. W. Supplementary Investigations of Infra-red Spectra. V. Infra-red Reflection Spectra. VI. Infra-red Transmission Spectra. VII. Infra-red Emission Spectra. Octavo, 183 pages, 107 text figures.
No. 102. Papers from the Tortugas Laboratory of the Carnegie Institution of Washington. Octavo, v + 191 pages, 41 text figures, 43 plates. This book contains the following papers:

Jordan, H. E.—The Germinal Spot in Echinoderm Eggs.
Jordan, H. E.—The Spermatogenesis of Aplopus mayeri.
Jordan, H. E.—The Relation of the Nucleolus to the Chromosomes in the Primary Oocyte of Asterias forbesii.
Brooks, W. K.—Pelagic Tunicata of the Gulf Stream: Part II, Salpa floridana. Part III, The Subgenus Cyclosalpa. Part IV, On Oikopleura tortugensis, a new Appendicularian from the Dry Tortugas, with Notes on its Embryology.
Brooks, W. K., and B. MacGlone.—The Origin of the Lung of Ampullaria.
Mayer, A. G.—The Annual Breeding-swarm of the Atlantic Palolo.
Mayer, A. G.—Rhythmical Pulsation in Scyphomedusæ.
Perkins, H. F.—Notes on Medusæ of the Western Atlantic.
Linton, Edwin.—Helminth Fauna of the Dry Tortugas.
Edmondson, C. H.—A Variety of Anisonema vitrea.

No. 103. Papers from the Tortugas Laboratory of the Carnegie Institution of Washington. Octavo, v + 325 pages, 62 text figures, 41 plates. This book contains the following papers:

Cowles, R. P.—Habits, Reactions, and Associations in Ocypoda arenaria.
Stockard, C. R.—Habits, Reactions, and Mating Instincts of the Walking-stick.
Stockard, C. R.—Studies of Tissue Growth: I. An Experimental Study of the Rate of Regeneration in Cassiopea xamachana.
Zeleny, Charles.—Some Internal Factors Concerned with the Regeneration of the Chelæ of the Gulf-weed Crab.
Chapman, F. M.—A Contribution to the Life-histories of the Booby and Man-o'-war Bird.
Conklin, E. G.—The Habits and Early Development of Linerges mercurius.
Conklin, E. G.—Two Peculiar Actinian Larvæ from Tortugas, Florida.
Watson, J. B.—The Behavior of Noddy and Sooty Terns.
Reighard, Jacob.—An Experimental Field-study of Warning Coloration in Coral-reef Fishes.

No. 104. Eigenmann, Carl H. The Blind Vertebrates of some American Caves: A study in Degenerative Evolution. Quarto, IX + 241 pages, 29 plates, 72 text figures.

No. 107. Chamberlin, T. C., *et al.* Contributions to Cosmogony and the Fundamental Problems of Geology. Octavo, IV + 264 pages, 19 text figures. This book contains the following papers:

I. The Tidal Problem:
- The Former Rates of the Earth's Rotation and their Bearings on Deformation. By T. C. CHAMBERLIN.
- The Rotation Period of a Heterogeneous Spheroid. By CHARLES S. SLICHTER.
- On the Loss of Energy by Friction of the Tides. By WILLIAM D. MACMILLAN.
- On Certain Relations Among the Possible Changes in the Motions of Mutually Attracting Spheres when distributed by Tidal Interactions. By F. R. MOULTON.
- Notes on the Possibility of Fission of a Contracting Rotating Fluid Mass. By F. R. MOULTON.
- The Bearing of Molecular Activity on Spontaneous Fission in Gaseous Spheroids. By T. C. CHAMBERLIN.

II. Geophysical Theories under the Planetesimal Hypothesis. By ARTHUR C. LUNN.

III. Relations of Equilibrium between the Carbon Dioxide of the Atmosphere and the Calcium Sulphate, Calcium Carbonate, and Calcium Bicarbonate of Water Solutions in Contact with it. By JULIUS STIEGLITZ.

No. 110. Jones, Harry C., and John A. Anderson. The Absorption Spectra of Solutions. Octavo, VI + 110 pages, 81 plates.

No. 111. Noguchi, Hideyo. Snake Venoms: An Investigation of Venomous Snakes with Special Reference to the Phenomena of their Venoms. Octavo, XVII + 315 pages, 33 plates, 16 text figures.

No. 112. Shull, G. H. Bursa bursa-pastoris and Bursa heegeri: Biotypes and Hybrids. (Paper No. 12, Station for Experimental Evolution.) Octavo, 57 pages, 4 plates, 23 text figures.

No. 113. Spalding, V. M. Distribution and Movements of Desert Plants. Octavo, V + 144 pages, 31 plates, 3 text figures.

No. 114. Castle, W. E., *et al.* Studies of Inheritance in Rabbits. (Paper No. 13, Station for Experimental Evolution.) Octavo, 70 pages, 4 plates.

No. 117. Cannon, W. A. Studies in Heredity as Illustrated by the Trichomes of Species and Hybrids of Juglans, Oenothera, Papaver, and Solanum. Octavo, III + 67 pages, 10 plates, 20 text figures.

No. 118. Richards, Theodore W., with collaboration of J. Hunt Wilson and R. N. Garrod-Thomas. Electrochemical Investigation of Liquid Amalgams of Thallium, Indium, Tin, Zinc, Cadmium, Lead, Copper, and Lithium. Octavo, III + 72 pages, 12 text figures.

Sales of Publications and Value of Those on Hand.

As may be seen from the fourth column of the first table on p. 26 there was a markt increase in the sales of publications during the year. This increase is likely to continue until a balance between the demand and the supply is reacht. There seems to be no doubt that this method of distributing the publications of the Institution is at once the most equitable, practicable, and economical at present attainable.

At the end of this fiscal year there were in storage in the Bond Building, Washington, D. C., 33,732 volumes, having a sale value of $61,829.80; and in storage in the Geophysical Laboratory, Washington, 24,941 volumes, having a sale value of $54,350. The total value of books on hand is therefore $116,134.80. In addition to these books there are 23,305 numbers of the Index Medicus on hand, having a sale value of $9,601. All of these books will be placed in fire-proof storage vaults on removal to the Administration Building.

ADDITIONAL SUGGESTIONS.

It should be understood by the Board of Trustees that with the end of this calendar year the accumulated income of the Institution is exhausted and that further development is restricted to current income. This income will suffice with careful management to maintain the efficiency of existing fruitful enterprises, but it will leave no room for expansion in the near future under present and prospectiv economic conditions. The Institution is well prepard to meet these conditions. It has acquird all of the essentials in the way of buildings, equipment, and preliminary experience to make its principal divisions of work highly effectiv. But it must be prepard, if necessary, to restrict the quantity of research undertaken in order to maintain the highest standards in quality. In view of these limitations it seems inopportune to do more than to recall attention to several new projects referd to in preceding reports and to state that several additional projects have been under consideration during the past year. Not the least interesting among the latter are several of a peculiarly international scope to which attention has been calld by foreign correspondents.

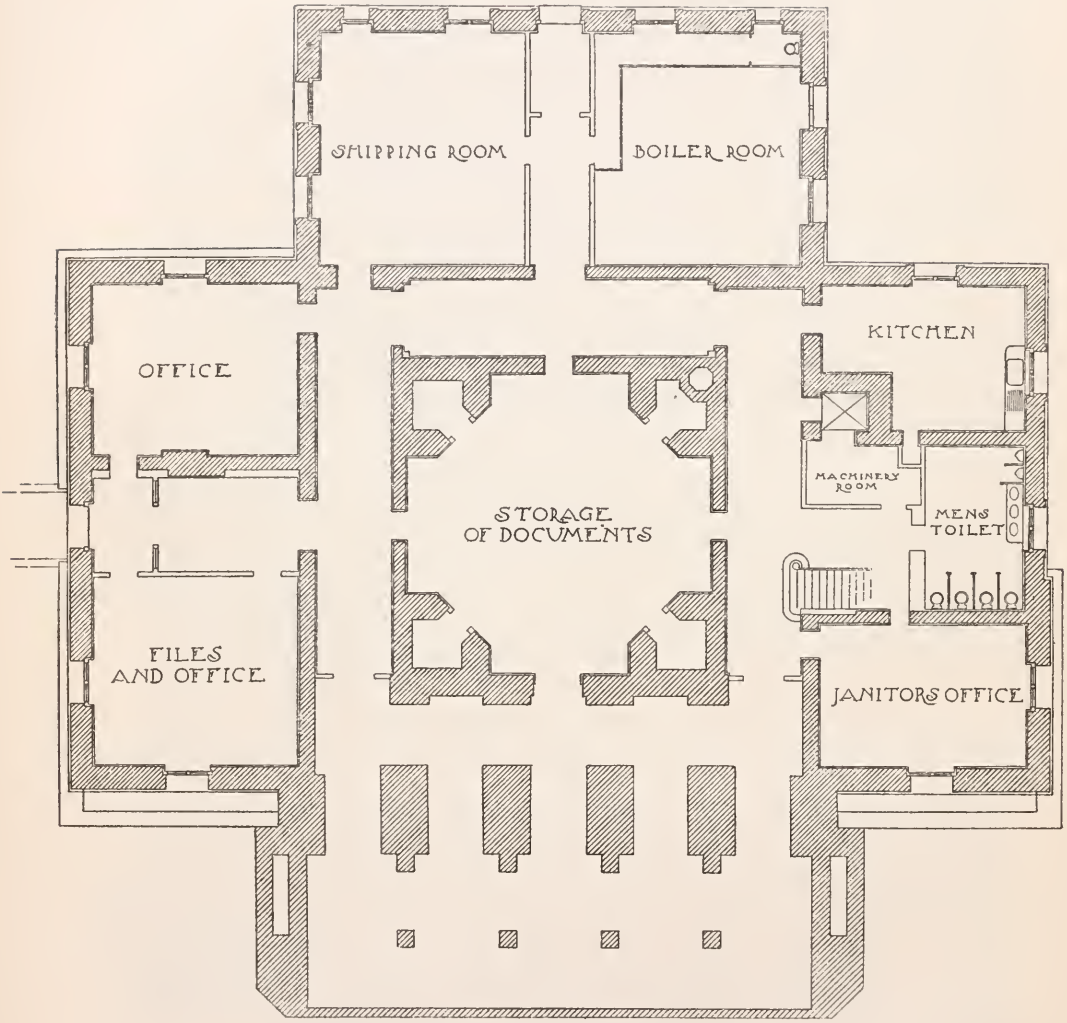
Limitations on Growth of Institution.

Experience in the Institution has demonstrated that our departmental system affords one of the most productiv methods of conducting research. It appears quite safe, in fact, to commend this as the method most worthy of attention in contemplating expansion into any large field of research requiring sustaind cooperativ effort. Similarly, experience has demonstrated that there are many investigations which may be carried to fruitful conclusions by individuals who require no special outlay for equipment and no large cooperating staff. Such individuals, properly chosen, are certain to produce good work in nearly every case.

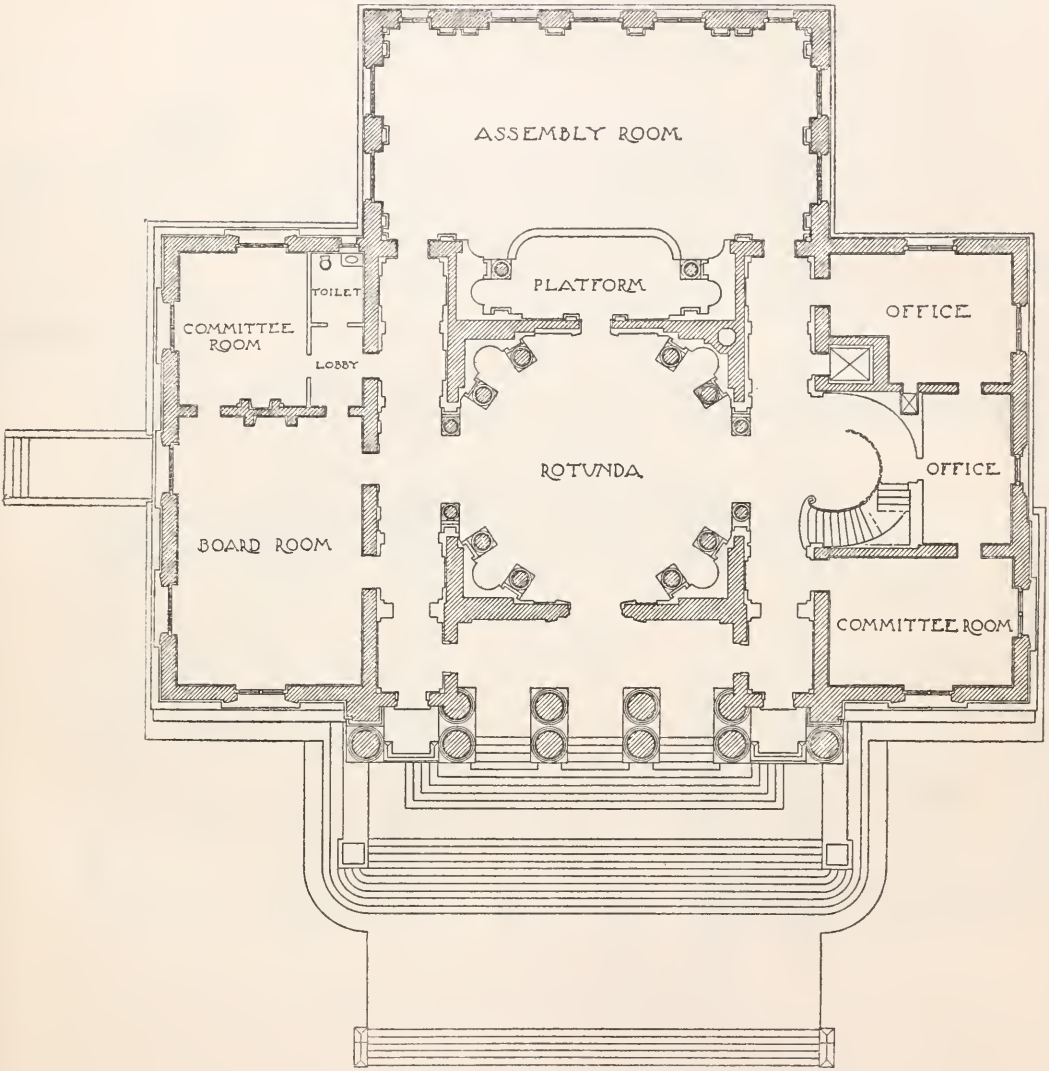
Effectiv Modes of Expansion.

These two safe methods of expansion are available therefore whenever opportunity for their application occurs. It seems especially desirable for the Institution to enlarge its number of research associates, drawn from the ranks of the leading contributors to current scientific progress. On the one hand, our departments in many cases need the counsel of these experts and some such might be advantageously permanently attacht to these departments. On the other hand, more of these eminent experts might be advantageously subsidizd in the pursuit of their independent researches.

PLATE 2.

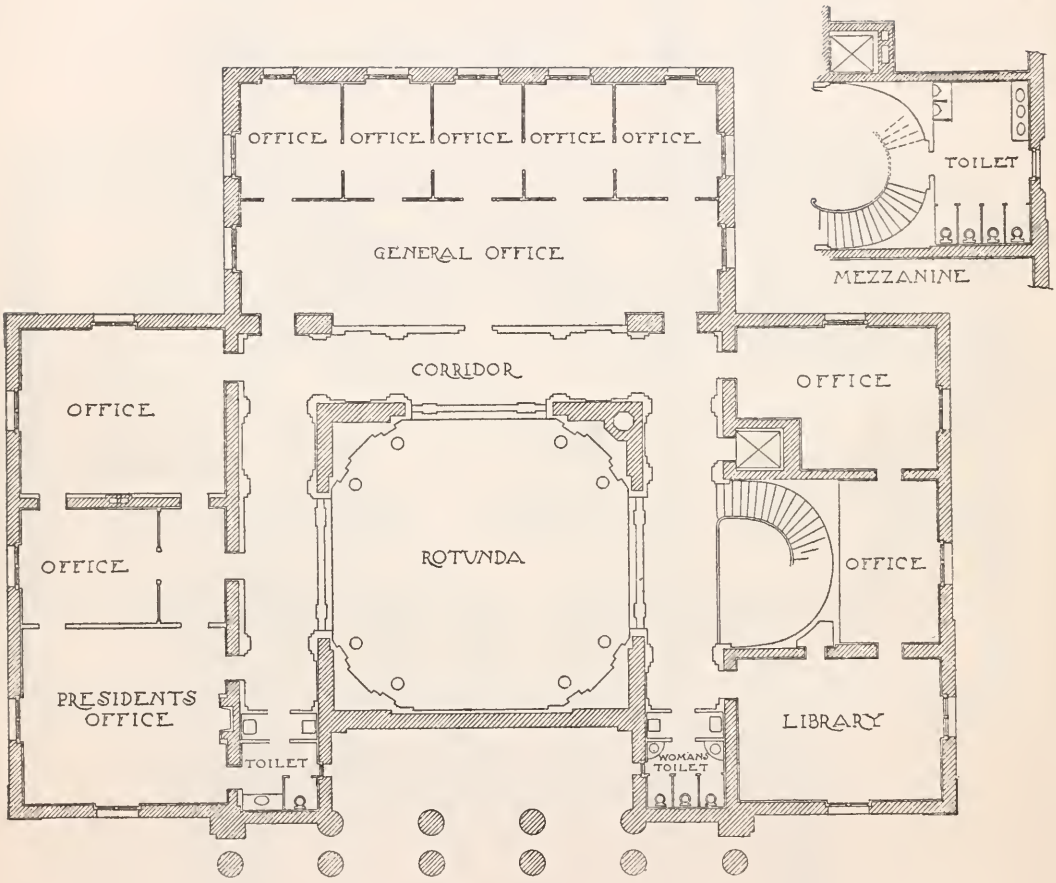


GROUND FLOOR PLAN, ADMINISTRATION BUILDING.



FIRST FLOOR PLAN, ADMINISTRATION BUILDING.

PLATE 4



SECOND FLOOR PLAN, ADMINISTRATION BUILDING.

REPORT OF THE EXECUTIVE COMMITTEE.

REPORT OF THE EXECUTIVE COMMITTEE.

To the Trustees of the Carnegie Institution of Washington:

GENTLEMEN: Article V, Section 3, of the By-Laws provides that the Executive Committee shall submit at the annual meeting of the Board of Trustees a report for publication, and Article VI, Section 3, provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for the year 1908–1909.

During the fiscal year ending October 30, 1909, the Executive Committee held nine meetings. Printed reports of these meetings have been sent to the members of the Board of Trustees.

At the meeting of the Board of Trustees on December 8, 1908, Messrs. Root and Walcott were elected to succeed themselves as members of the Executive Committee for a term of three years, and Messrs. Parsons and Welch were elected to succeed Messrs. Gilman and Wright for the term ending in 1909.

Upon the adjournment of the Board of Trustees on December 8, 1908, the members of the Executive Committee met and organized by the election of Mr. Welch as Chairman for 1909, and by voting that Mr. Gilbert, Assistant Secretary of the Institution, act as Secretary of the Committee for the same period.

The President's report gives in detail the results of the work of the Institution for the fiscal year 1908–1909, together with various recommendations and suggestions, and also an outline of suggested appropriations for the fiscal year 1909–1910. The Executive Committee hereby approves the report of the President, and his recommendations, as the report and recommendations of the Committee.

The Chairman of the Board of Trustees, in accordance with the By-Laws of the Institution, notified the Committee, at the meeting of October 20, 1909, that he had designated the American Audit Company to audit the accounts of the Institution for the fiscal year ending October 30, 1909, and the report of this company is herewith submitted as a part of the report of the Executive Committee.

There are also submitted a financial statement and a statement of receipts and disbursements for the year, together with a statement of aggregate re-

ceipts and disbursements since the organization of the Institution on January 28, 1902.

It becomes the duty of the Executive Committee to report the death of Dr. Carroll D. Wright, a former Trustee of the Institution, on February 20, 1909, the death of Hon. William Wirt Howe, a former Trustee, on March 17, 1909, the death of Hon. Ethan Allen Hitchcock, a Trustee, on April 9, 1909, and the death of Judge William Lindsay, a Trustee, on October 15, 1909.

Two vacancies in the Board of Trustees are created by the deaths of Mr. Hitchcock and Judge Lindsay. Other vacancies are created by the non-acceptance of election of Mr. Charles W. Eliot and by the resignation of Mr. D. O. Mills. These four vacancies will call for action at the coming annual meeting. The terms of office of Messrs. Mitchell, Parsons, and Welch as members of the Executive Committee, and the terms of office of Mr. Billings as Chairman of the Board of Trustees, of Mr. Root as Vice-Chairman, and of Mr. Dodge as Secretary, will expire at the time of the coming annual meeting, as will also the terms of office of Messrs. Higginson and Low, as members of the Finance Committee, making, with the resignation of Mr. Mills, three vacancies in this latter Committee to be filled.

The Executive Committee calls attention to the fact that the income of the Institution is now practically absorbed by the budget, and that there are several important lines of investigation which the Institution could advantageously pursue but which must be deferred through lack of the necessary funds.

William H. Welch, *Chairman.*
John S. Billings.
Cleveland H. Dodge.
S. Weir Mitchell.
Wm. Barclay Parsons.
Elihu Root.
Charles D. Walcott.
Robert S. Woodward.

December 13, 1909.

Financial Statement, October 30, 1909.

		ASSETS.	LIABILITIES.
Endowment			$12,000,000
Reserve Fund:			
Administration Building Fund			307,520.84
Surplus of Building Fund			1,911.51
Premium from sale of bonds			2,450
Insurance Fund and accrued interest			15,450
Bonds (original cost):			
U. S. Steel Corporation bonds, 5 per cent		$12,000,000	
$100,000 A., T. & S. Fe Ry. Co. 4 per cent 100-year gold bonds, Oct. 1, 1995		100,112.50	
$50,000 L. S. and Mich. S. Ry. 4 per cent debenture bonds		48,222.22	
$50,000 C. Pacific First Refunding gold 4 per cent bonds		51,937.50	
Real Estate, Equipment, and Publications:			
Administration:			
Building and site (chargeable to Administration Building Fund)	$249,981.15		
Furniture	4,437.63		
		254,418.78	
Publications:			
Stock on hand and outstanding accounts		126,648.92	
Department of Botanical Research (September 30, 1909):			
Buildings, office, and library	$22,880.53		
Apparatus	5,701		
Operating appliances	6,124.58		
		34,706.11	
Department of Experimental Evolution (September 30, 1909):			
Buildings, office, and library	36,339.58		
Laboratory apparatus	2,586.49		
Operating appliances	7,079.79		
		46,005.86	
Geophysical Laboratory (September 30, 1909):			
Building, library, operating appliances	107,874.22		
Laboratory apparatus	55,087.06		
Shop equipment	10,262.07		
		173,223.35	
Department of Marine Biology (September 30, 1909):			
Vessels	12,712.55		
Buildings, docks, furniture, and library	9,311.83		
Apparatus and instruments	1,320.02		
		23,344.40	
Department of Meridian Astrometry (June 30, 1909):			
Buildings and operating appliances	13,507.94		
Apparatus and instruments	2,090.94		
		15,598.88	
Nutrition Laboratory (September 30, 1909):			
Building and office	106,861.03		
Laboratory apparatus	8,577.73		
Shop equipment	1,592.21		
		117,030.97	
Carried forward		12,991,249.49	12,327,332.35

Financial Statement, October 30, 1909—continued.

Real Estate, Equipment, and Publications—Cont'd.			
Brought forward		$12,991,249.49	$12,327,332.35
Solar Observatory (August 31, 1909):			
Buildings, grounds, road and telephone line	$103,325.76		
Shop equipment	17,012.63		
Instruments	222,241.97		
Furniture and operating appliances	33,505.02		
Hooker telescope	27,525.93		
		403,611.31	
Department of Terrestrial Magnetism (September 30, 1909):			
Office	3,934.40		
Instruments	22,899.22		
Vessel and ocean equipment	111,512.11		
Land equipment	614.74		
		138,960.47	
Property Investment (aggregate cost)		.....	1,083,567.90
Grants:			
Large		.....	108,931.52
Minor		.....	14,945.02
Research Associates and Assistants		.....	10,335.80
Publication		.....	82,169.12
Administration		.....	13,417.76
Cash:			
In banks		118,178.57	
Stamps and petty cash fund		300	
Unappropriated Fund		.....	11,600.37
		13,652,299.84	13,652,299.84

REPORT OF AUDITOR.

WASHINGTON, D. C., *November 19, 1909.*

The Executive Committee, Carnegie Institution of Washington.

GENTLEMEN: The books and accounts of the Carnegie Institution of Washington have been audited by us from November 1, 1908, to October 30, 1909, by authority of the Chairman of the Board of Trustees.

The income from the Endowment Fund and from investments has been duly accounted for and the expenditures have been regularly authorized and are supported by proper vouchers.

On Monday, November 8, 1909, the undersigned, Mr. Otto Luebkert, in company with the Chairman of the Board of Trustees, attended at the vaults of the Hudson Trust Company, Hoboken, N. J., and examined the bonds of the Endowment Fund, finding same on hand and in proper order.

On Thursday, November 18, 1909, Mr. Luebkert, in Company with the Bursar, Mr. John L. Wirt, and the Assistant Secretary, Mr. W. M. Gilbert, visited the vaults of The American Security and Trust Company, Washington, D. C., and examined and found correct and in good order the securities comprising the Reserve Fund and Investment accounts.

Respectfully submitted.

THE AMERICAN AUDIT COMPANY,
By OTTO LUEBKERT, *Resident Manager.*

Approved:
F. W. LAFRENTZ, *President.*

[Seal of The American Audit Company, New York.]

Attest:
A. F. LAFRENTZ, *Secretary.*

BIBLIOGRAPHY OF PUBLICATIONS RELATING TO WORK ACCOMPLISHED BY GRANTEES AND ASSOCIATES.

Under this heading it is sought to include the titles of all publications bearing upon work done under grants from the Carnegie Institution of Washington. In the list for the past year, as shown below, there may be some omissions, although it has been the endeavor to make it as complete as possible, and in some cases titles may be included which have only an indirect connection with such work. A list of the works published by the Institution during the year will be found in the President's report.

ACREE, S. F. Studies in catalysis: On the formation of esters from amides and alcohols. (Amer. Chem. Jour., 41, 457. June, 1909.)

———, and SLAGLE, E. A. On the theory of indicators and the reactions of phthaleins and their salts. (Amer. Chem. Jour., 42, 115. Aug., 1909.)

———. See REID, E. E.

ALLEN, E. T., and WHITE, W. P. Diopside and its relations to calcium and magnesium metasilicates. (Amer. Jour. Sci., v. XXVII. Jan., 1909.)

ASTON, JAMES. See BURGESS, C. F.

BARUS, C. Absence of polarization in artificial fogs. (Amer. Jour. Sci., v. XXVII, p. 402. 1909.)

———. The electrometer method of standardizing the coronas of cloudy condensation. (Proc. Amer. Phil. Soc. April, 1909.)

———. Coronas with mercury light. (Amer. Jour. Sci., v. XXVII, pp. 73–81. 1909.)

———. Thomson's constant *e*, found in terms of the decay constant of the ions within the fog chamber. (Amer. Jour. Sci., v. XXVI, pp. 324–328. 1908.)

———. The voltaic potential difference between the conductors of a condenser, separated by an ionized medium. (Proc. Amer. Phil. Soc. April, 1909.)

———, and BARUS, M. On an adjustment for the plane grating similar to Rowland's for the concave grating. (Proc. Amer. Phil. Soc. April, 1909.)

BATESON, WILLIAM. Mendel's principles of heredity. (pp. XIV + 396, Cambridge, England, 1909.)

———, SAUNDERS, Miss E. R., and PUNNETT, R. C. Experimental studies in the physiology of heredity. (Reports to the Evolution Committee of the Royal Society. Report IV.)

BAUER, L. A. On the apparent alterations of mass disclosed by weighings of magnets. (Ter. Mag., v. XIV, No. 2, pp. 72–76. June, 1909.)

———. Solar activity and terrestrial magnetism. (Abstr. Science, v. XXIX, No. 751, pp. 831–832. May 21, 1909.)

———. A plea for terrestrial and cosmical physics. (Science Monthly Weath. Rev., v. XXIX, No. 745, Apr. 9, 1909, pp. 566–570; v. 37, No. 1, pp. 27–29, Jan., 1909.)

———. United States magnetic tables and magnetic charts for 1905. (Abstr. Terr. Mag., v. XIV, No. 1, pp. 41–53. March, 1909.)

———. The magnetic survey of Africa. (Nat. Geog. Mag., v. XX, No. 3, pp. 291-292. March, 1909.)

———. The magnetic survey yacht *Carnegie* and her work. (This article originally formed contents of a souvenir pamphlet distributed at the launching of the *Carnegie*, June 12, 1909. Ter. Mag., v. XIV, No. 2, pp. 57–66. June, 1909.)

———. Some data regarding recent magnetic storms. (Abstr., Science, v. XXIX, No. 742, p. 468. March 19, 1909.)

BAUER, L. A., Mrs. The launching of the *Carnegie*. (Ter. Mag., v. XIV, No. 3, pp. 135–136. Sept., 1909.)

BAXTER, G. P., and COFFIN, F. B. A revision of the atomic weight of arsenic. (Proc. Amer. Acad. Arts and Sci., 44, pp. 179–197; Jour. Amer. Chem. Soc., 31, pp. 297–309; Zeit. anorg. Chem., 62, pp. 50–68. Jan., 1909.)

———, and TILLEY, G. S. A revision of the atomic weights of iodine and silver. Preliminary paper: The analysis of iodine pentoxide. (Jour. Amer. Chem. Soc., 31, pp. 201–221; Zeit. anorg. Chem., 61, pp. 293–319. Feb., 1909.)

BAXTER, G. P., MUELLER, E., and HINES, M. A. A revision of the atomic weight of chromium. First paper: The analysis of silver chromate. (Proc. Amer. Acad. Arts and Sci., 44, pp. 401–417; Jour. Amer. Chem. Soc., 31, pp. 529–541; Zeit. anorg. Chem., 62, pp. 313–330. March, 1909.)
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REPORTS ON INVESTIGATIONS AND PROJECTS.

The following reports and abstracts of reports show the progress of investigations carried on during the year, including not only those authorized for 1909, but others on which work has been continued from prior years. Reports of Directors of Departments are given first, followed by reports of recipients of grants for other investigations, the latter arranged according to subjects.

A.—ACCLIMATIZATION LABORATORY, CARMEL, CALIFORNIA.

B.—BREEDING LABORATORY (ADOBE BUILDING), TUCSON, ARIZONA.

DEPARTMENT OF BOTANICAL RESEARCH.*

D. T. MacDougal, Director.

The activities of the members of the staff during the year have been chiefly directed to the reduction of data, the collocation of observations, and the carrying out of special series of experiments for the completion of work upon problems that have been under investigation for some time. The operations of the Department have been extended by the establishment of the laboratory at Carmel, California, which will be devoted chiefly to acclimatization experiments. This, together with the alluvial experimental garden at Tucson, makes the equipment very effective for the analysis of the influence of climate on plants, with respect to heredity and evolution. Title to the Tucson garden has been acquired and the garden has been improved. Cooperation of the Department with other institutions and individuals has been gratifyingly successful, as described in the following pages. Geologists, zoologists, climatologists, and botanical specialists of all kinds are making an increasing use of the facilities of the Desert Laboratory.

MOVEMENTS OF VEGETATION IN THE SALTON BASIN.

The level of the Salton Lake had fallen 135 inches in October, 1909, below the maximum of February, 1907. The salt-content of the water, which was 333 parts in 100,000 at the maximum, was found to have increased to 520 in samples taken in June, 1909. The older beaches bared during the summer of 1907 are now fast approaching the conditions of soil moisture characteristic of deserts and prevalent before the formation of the lake. In previous reports some notice has been given of the occupation of these beaches by vegetation, and now the tops of some small hills in the basin are being uncovered as islands and offer foothold for plants. The earliest occupants have been seen on a few of these, and the use of these islands as nesting-places by pelicans and penguins has given opportunity for observing their agency in the dissemination of seeds.

The members of the staff have had the benefit of the advice and counsel of several specialists in connection with this work. Prof. W. P. Blake, territorial geologist of Arizona, and the discoverer of the sub-sea-level basin in which the lake lies, has been in frequent consultation. Prof. C. F. Tolman, of the University of Arizona, accompanied an expedition around the lake in November, 1908, and gave some helpful interpretations of certain geological phenomena. Prof. W J McGee, Mr. E. E. Free, and Dr. James M. Bell, of

* Situated at Tucson, Arizona. Grant No. 537. $32,000 for investigations and maintenance. (For previous reports see Year Books Nos. 2, 3, 4, 5, 6, and 7.)

the Bureau of Soils, U. S. Department of Agriculture, visited the lake with a party from the Desert Laboratory in June, 1909, and rendered valuable assistance.

It seems probable that the principal generalizations as to revegetation may be made upon the basis of facts to be obtained within the next three or four years, and it is proposed to organize a commission of persons, within and without the Department, to give thorough attention to the various features of the work.

ACCLIMATIZATION: THE INDUCTIVE INFLUENCE OF CLIMATIC COMPLEXES UPON ORGANISMS.

The problems outlined in my report for 1908 have received continued attention. The obvious reactions in the way of morphogenic alterations exhibited by plants under environmental conditions different from those characteristic of their habitats are being tested as to their hereditary character, and effort is being directed to obtaining evidence of influences exerted on germ-plasm. The specialized cultures of Professor Tower with the chrysomelid beetles will be dealt with in a separate section.

The establishment and successful culture of series of plants in the plantations at 8,000 and 5,000 feet in the Santa Catalina Mountains and at the Desert Laboratory have demonstrated that an additional location, furnishing equable conditions of climate, is necessary to obtain well-rounded evidence upon some features of the work. Such conditions had been found by two years' test by Dr. W. A. Cannon at Carmel, 4 miles south of Monterey, California. The precipitation record for this place for nine years gives the following averages: January 3.2, February 3.3, March 3.9, April 1.62, May 0.8, June 0.16, July 0, August 0.06, September 0.67, October 1.18, November 2.57, December 2.57.

The rainfall is seen to occur in a single season, with the maximum in midwinter. The minimum temperatures are in the neighborhood of the freezing-point, with a few maxima of 90° F. or over in the summer, but for the most part the thermographic curve lies between 40° F. and 75° F. These conditions permit the culture of plants from the mountain plantations, from the Desert Laboratory, and from a wide range of territory on the eastern seaboard.

The Carmel Development Company, learning the needs of the Department, offered to donate a building and ground suitable for the work, and this offer was accepted by the Trustees of the Institution in December, 1908.

Messrs. Cannon and MacDougal visited Carmel the last week in April, 1909, and installed a series of experimental cultures, and also presented the plans for the laboratory to be erected, which had been designed by Mr. G. Sykes, engineer of the Department. This matter was promptly taken in hand by the donors and the laboratory was delivered to the Department ready for

occupancy July 1, 1909. The building comprises two main rooms for microscopic and photographic work, a work-room, store-room, and dark-room; it is furnished with water and has an independent acetylene plant for light and heat in the laboratory. The location on the brow of a hill facing to the eastward, overlooking the valley of a tributary of the Carmel River, in which the well-watered garden lies, is an ideal one for the experimentation in hand. The grounds also include wooded slopes and hilltop area well suited for dealing with wild plants. The representatives of the Carmel Development Company have lost no opportunity to learn the needs of the Department and have been quick to meet these needs voluntarily.

CORRELATED INVESTIGATIONS.

Alterations in Heredity Induced by Ovarial Treatment (by Dr. D. T. MacDougal):

The study of the effects of the treatment of the ovarial apparatus of plants with solutions of various chemical constituency, begun in 1905, has been continued. Up to this time results have been obtained with species of *Oenothera, Raimannia, Carnegiea,* and *Penstemon;* a large number of seedlings representing experimentation with other genera are under observation. The available results of these experiments, supported by those of Gager using radium as an exciting agent and those of Tower in the application of climatic factors, point indubitably to the conclusion that it is possible to induce changes in germ-plasm whereby its transmission of hereditary characters may be greatly altered. Some of the alterations take the form of accentuated or strengthened fluctuations of qualities characteristic of the plants treated, while in other cases the derivatives behave as mutants or newly arisen forms. The fact that some of these have been cultivated successfully to the fifth generation, without reversion or exhibition of pathological characters, gives special importance to these results.

The derivative of *Oenothera biennis* which was obtained early in the investigation has been hybridized with its parent, with a result that the form produced by the cross is more vigorous than either parent. Parental forms and derivatives obtained by ovarial treatments are being grown in the various acclimatization plantations to test their capacity for survival under different conditions. As might be expected, their hardiness is not identical under the various conditions into which they are thus thrown.

No further theoretical explanation of the mechanism of such changes is offered except that they may be induced in the germ-cells after the reduction divisions have taken place and previous to fertilization. The alterations in question may be induced in either the egg or sperm, a fact not yet determined, and may consist in disturbances of the autolytic action of the cell, by which catalytic processes are inhibited; or the departure might be due wholly to the

direct catalytic action of the reagents used, since the opinion grows in strength that the salts used, when present in the plant, sustain chiefly a catalyzing function in the cell.

The Water-balance in Succulents (by Dr. D. T. MacDougal):

The observations on the variation and composition of the solutions accumulated in the bodies of cacti and other desert plants have been brought to a stage where the results seem worthy of presentation in a paper now being completed. In all of the forms tested growth and reproduction are dependent on the presence of the full capacity of the plant, but such plants may be separated from an available supply for extended periods without injury. The ratio of transpiration to the amount present is such that long periods are necessary to deplete the balance to a point where the plant perishes from lack of water. The absorbing capacity of the roots of such plants is far in excess of their needs during any given period. The concentration of the dissolved salts of course increases with the loss of water from cell-sap, but no marked change in acidity ensues. Plants have been deprived of over 70 per cent of their water-balance without serious injury, the depleting process being extended over many months or years in some tests.

Specialized desert plants are of two types, spinose forms and succulents. The absence of these forms from the fossil records justifies the conclusion that the cacti and other xerophytes have originated since the beginning of the Pleistocene. The earliest step in the action by which xerophytic plants were produced would consist in the reduction of the members of the shoot from which thorny or spinose plants would be produced. A second step, which might be in progress at the same time as the first, would consist in the enlargement of tissues containing water producing the succulents. Such plants with a large water-balance therefore represent the most advanced stage of vegetative development in the movement by which vegetation has gradually occupied the dry land and as a very recent development has invaded the desert.

Origination of Parasitism (by Dr. D. T. MacDougal):

A consideration of the general relations of the large water-balance carried by succulents led to the suggestion that this material might offer conditions highly favorable to the development of parasitism among the seed-plants. After much preliminary experimentation it has been found that healed or regenerated cuttings of species which propagate readily by this means might continue existence and make growth when the emerging roots were allowed to penetrate the tissues of another living plant as a substratum, as announced in the report for 1908. Such cases of *xeno-parasitism* may be more or less permanent, as some of the preparations made in 1908 are still in existence. The results in question are to be sharply distinguished from grafts, in which

a union of tissues is effected although the junction may be indirect. The parasitic relation under discussion is such that the dependent partner of the union receives liquid material through its own proper absorbing organs. A comprehensive series of chemical tests is being made to ascertain the acidity and salt-content of the plants used as host and dependent in these experiments. The osmotic pressure is probably the most important limiting factor in all dependent nutritive arrangements.

The recent discovery of parasitism by green plants ordinarily autophytic suggests that this relation may originate fortuitously and the experimental results obtained promise some definite information as to the conditions favorable to such a change in seed-plants, which should also be considered in other parasitic arrangements.

Growth and Alterations in Form and Volume of Succulents (by Mrs. E. S. Spalding):

The series of measurements by which the principal changes in form and volume of some of the larger cacti have been detected have now been carried through a fifth year. The data obtained show that the water-balance of the succulents of the Arizona deserts increases to a maximum during the two rainy seasons and decreases during the two intervening dry periods, being accompanied by changes in form and size which may be readily calibrated. In addition to actual shrinkage and swelling, the external ridges of columnar or cylindrical cacti exhibit specialized movements. These, as well as flower-formation and growth, are influenced by local exposure, so that the northern and southern sides of a plant display marked differences. Some of the changes are not readily assignable to known causes. The complete results will be presented in a paper now in course of preparation.

Relation of Evaporating Capacity of the Air to Plant Distribution (by Dr. F. Shreve):

A secure basis for studies in plant distribution is to be found only in the results of analyses of habitat conditions, and Dr. Shreve has cooperated extensively with Dr. Livingston in the reduction of atmometric data from which a vegetational map of North America has been prepared.

Activities of Plants of Tropical Rain-Forests (by Dr. Forrest Shreve):

Dr. Shreve has spent the latter half of the year at the Tropical Laboratory of the New York Botanical Garden, at Cinchona, Jamaica, where a continuation of his studies upon the growth, transpiration, and photosynthesis of certain species has been carried out. Special attention has been paid to the influence of high relative humidity and cloudiness upon the collective activities of tropical forms to obtain data for contrast with observations made in the desert. The rate of transpiration is found to follow closely the rate of evaporation, stomatal movement being always very slight and relatively unimportant as a regulative factor.

The conditions mentioned result in a slow rate of growth in seed plants. The ferns, however, are able to maintain rapid rates of growth, and display transpiratory behavior of a different character.

The Distribution and Movements of Desert Plants (by Dr. V. M. Spalding):

The studies of Prof. V. M. Spalding on the distribution and movement of desert plants have recently appeared in publication No. 113 of the Carnegie Institution of Washington. In course of its preparation local and comparative studies were conducted in various parts of the southwestern United States, which have been reported in part in the Plant World and elsewhere. The journal named has come under the editorial direction of Professor Spalding and, in addition to much other material, has been made to include contributions covering a wide range from members of the staff of the Desert Laboratory.

Evaporation and Other Climatic Factors in Relation to Distribution of Plants (by Dr. B. E. Livingston):

The records of the evaporation rates by the use of the porous cup-atmometer, which were obtained by Dr. Shreve and a number of collaborators during 1908, were reduced and from the corrected data obtained the isoatmic lines of United States and Canada for the summer season of 1908 were plotted. Such evaporation data promise to supply the missing factor which has rendered attempts to relate plant distribution to climatology so unsatisfactory. The calculation of the evaporation-rainfall ratio for the summer season for several stations is now in progress.

Atmometry and the Relation of Evaporation to Other Factors (by Dr. B. E. Livingston):

The porous cup-atmometer and the methods for its operation have been improved, new and satisfactory means of calibration have been devised, and a number of secondary influences of climate and exposure upon the cups have been analyzed, so that the instrument is now available for use by any careful observer. Methods have been devised for the ready determination of the influence of wind, relative humidity, and temperature upon evaporation. The importance of the atmometer in ecological studies, as indicated by the work of Transeau, Gager, and Yapp, and by various researches at the Desert Laboratory, has led to a fairly successful attempt to analyze the behavior of the instrument under extraordinary conditions.

The Physics of Transpiration in Plants (by Dr. B. E. Livingston):

The quantitative study of the physics of water-loss in desert plants has been continued. The results of 1908, to the effect that the evaporating power of the air and the stomatal movement determine the amount of transpiration in light of a certain intensity only, have been corroborated. It now seems possible to calculate transpiration from the measured intensities of the

illumination, the evaporating power of the air, and the daily curve of stomatal movement. In connection with this work a modification of the porous cup-atmometer has been found to serve admirably as a solar radio-integrator, and promises to be of great usefulness in ecological research.

Soil-moisture in Relation to Plant Growth (by Dr. B. E. Livingston):

Progress has been made in the improvement of methods for measurement of moisture conditions in the soil. Data have been obtained of the actual moisture-content of four types of soils in the domain of the Desert Laboratory for a complete year and a number of other determinations are being made. These, together with the data of precipitation and of general plant activity, will go far toward solving a number of problems connected with the seasonal fluctuations in growth and other functions of desert vegetation.

The Root-Habits of Desert Plants (by Dr. W. A. Cannon):

The study of the mode of branching, extent, and position in the soil of a number of types of annual and perennial desert plants indigenous to the Tucson region has been brought to a stage approaching completion. It has been necessary to take into account the interrelations of the roots of different species growing in the same habitat, the influence of the substratum, and the amount and character of the rainfall with respect to its periodicity in applying the results to the interpretation of distribution.

The roots of the more pronounced types of desert species, such as those inhabiting the arid bajadas and mountain slopes, do not penetrate deeply, partly by reason of the presence of rock strata or impenetrable hardpan and partly because the moisture from the rains does not penetrate beyond a very few feet, the amount of soil-moisture being less at 8 feet than at 1 or 2 feet below the surface. Where rock-crevices containing water are found in the alluvium along streamways, a penetration similar to that in well-watered regions is found.

A general census of the plants examined shows that the spinose forms, such as *Kœberlinia,* send their roots more deeply than those which accumulate a large water-balance like the cacti. Although no minute examination has been made, there does not appear to be any special type of structure of the absorbent organs of desert plants, their fitness being wholly one of habit. Many of the species observed show a relatively great development of long thin roots capable of rapid absorption with the beginning of the moist midsummer, and these organs perish with the decrease of the soil-moisture content.

The thickness of the layer of soil above an underlying hardpan or impervious layer naturally affects the character of the root-systems and also the nature of the competition among species. The roots of individuals of the same species may interweave to make very dense tangles, but no direct competition may ensue between different species growing near together, as

their roots occupy horizontal layers at different depths. Competition therefore takes place between species which spread out their roots at the same depth, and in this regard the luxuriant growth of annuals characteristic of the moist midwinter and of the moist midsummer may come into direct competition with the perennials which send their roots to the same depths.

The type of root-system, or rather the habit of the root-system, of a species is a determining factor in local distribution of desert plants to a much greater extent than it may be in the plants of moist regions. Some species, such as the creosote-bush (*Covillea*), which have a general habit and great plasticity, are capable of living in a wide variety of habitats, while such forms as the sahuaro (*Carnegiea*) which require both anchorage and great superficial extension of the root-systems, are necessarily confined to certain narrow types of habitats, although disseminated over a wide extent of territory.

Parasitism in Desert Plants (by Dr. W. A. Cannon):

The critical examination of the root-systems of many hundreds of plants indigenous to the Tucson region brought to light many facts of interest in connection with the prevalence and origination of parasitism. *Orthocarpus purpurascens,* one of the annual Scrophulariaceæ, was found to fasten to the roots of nearly twenty species of plants, all but two of which are annuals. Several other members of the family of *Orthocarpus* have long been known to be parasitic, but information as to the habits of this plant was lacking.

Two species of *Krameria, K. canescens* and *K. parvifolia,* of the family of Krameriaceæ, were found to be parasitic on a number of woody perennials, inclusive of trees, shrubs, and cacti, and the hosts are of both the spinose and succulent types. The parasitism of *Krameria* is very destructive to its hosts, in consequence of which no unions of any great age could be found. The minute structure of the haustoria, or penetrative and absorbent structures, of the parasite have been followed and display many features of interest which will be described in a paper now in course of preparation. The establishment of the parasitic relation was followed experimentally, using *Parkinsonia aculeata* as a host.

A South American species of *Krameria* has been an article of commerce for a long period, the roots yielding a dye used in coloring wines, but no mention seems to have been made of any parasitism of this plant. The attachment to the host is made by long, thin roots, which might easily be destroyed in digging, and it is quite probable that a careful examination of the South American species would show that it also fastens to the roots of neighboring species.

Inheritance of Structural Characters in Hybrids (by Dr. W. A. Cannon):

Dr. Cannon has completed the proofs of his paper (Publication No. 117) on the inheritance of structural characters in hybrids, and has made some further tests which confirm the conclusions set forth in the paper. In the

instance of the "wonderberry," one of the products of Mr. Burbank's breeding operations, the hairs were found to be of the same type as *Solanum guinense,* one of the parents, while the general appearance of the plant, taking most of its characters into account, is much like that of *Solanum villosum,* according to Mr. Burbank's report.

COOPERATIVE ARRANGEMENTS.

Some very profitable arrangements by which the facilities of the Department have been placed at the disposal of investigators not on the staff are to be reported.

Observations at the geographically arranged series of atmometer stations planned by Messrs. Livingston and Shreve have been continued by various observers, and their unselfish application to the details has materially forwarded the investigations described in the previous pages.

The work of Dr. I. D. Cardiff, of Washburn College, Topeka, Kansas, on certain forms of the walnut (*Juglans nigra*), suggestive of a hybridization with the hickory, has been thought of such importance that assistance has been given for the purpose of making observations of the habits of the living trees in northern Indiana and Tennessee and securing material for exact morphological studies.

Mr. W. D. Hoyt, of Johns Hopkins University, has carried an investigation of the rhythmic action of the seaweed *Dictyota,* in fruiting, to a stage where it seems that this phenomenon may be made to yield evidence of value as to the inheritance of an acquired character.

The constitution of the water of the Salton Lake is undergoing progressive modification with the age of the lake and with the decreasing depth. The analyses of the water made by the cooperation of Dr. W. H. Ross and Prof. R. H. Forbes, of the Agricultural Experiment Station, University of Arizona, furnish data of the greatest value in various phases of the problems under consideration, with respect to the revegetation of this basin. Dr. Ross has also carried out a large number of accurate estimations of the salt-content and acidity of plants used for experimental purposes in studies of the water-balance and of the origination of parasitism.

Professors F. E. Lloyd and J. E. Kirkwood spent a year in the service of the Mexican Continental Rubber Company, being engaged in a study of the culture and conservation of the Mexican desert rubber plant guayule (*Parthenium argentatum* Gray). The geographic distribution of this plant, the fact that it belongs to a family in which, so far, it is the only species furnishing rubber industrially, and the nature of the product, together with the general features of its habit and growth, make it of great interest. In accordance with a working plan agreed upon, Dr. Kirkwood spent from November, 1908, to July, 1909, at the Desert Laboratory, completing germination tests and embryological studies, while Professor Lloyd gave attention

to the rate of growth, density of distribution, methods of propagation, and morphology in his own laboratories at the Alabama Polytechnic Institute at Auburn, Alabama.

Dr. T. Whittelsey, of Northwestern University, who also gave a year of service to a study of the chemistry of the products, has continued his work and will join with Professor Lloyd in preparing a manuscript dealing with the entire matter, which will be presented for publication shortly.

The Influence of Environmental Factors upon Beetles in Pure Lines and in Hybridization (by Prof. W. L. Tower):

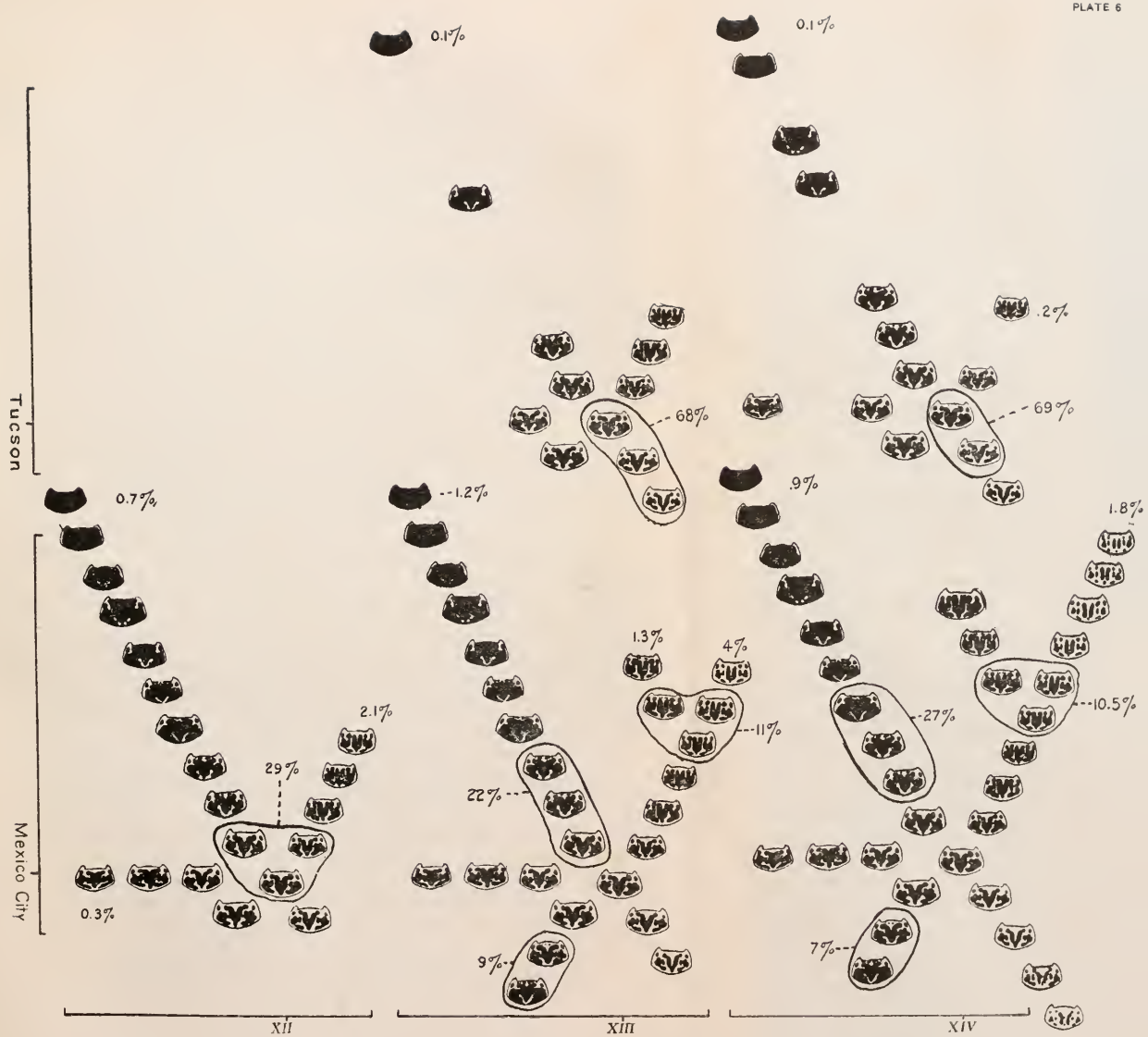
The investigations of Prof. W. L. Tower, of the University of Chicago, upon the reaction of the chrysomelid beetles to environmental or climatic factors, have now been carried through the second year at the Desert Laboratory, and the following communication from him describes the progress attained:

That portion of my work which has been carried on at the Desert Laboratory during 1909 consisted in the continuation of the work of 1908, its expansion, and the addition of much new material. Tucson affords a typical desert environment, and all of the experiments placed at Tucson, thus far, are arranged to give exact data concerning the action of the physical portion of a desert habitat upon the animal organism.

Three distinct sets of experiments are being conducted at Tucson, as a part of a larger series which is planned to give precise information upon three vital processes in the evolution of organisms, viz: (1) The action of the physical environment upon species and races migrating into or suddenly introduced into new environmental complexes; (2) the action upon and the relation of the physical environment to the processes of variation, heredity, elimination, and conservation; (3) the relation of the physical environment to the interaction between two or more freely interbreeding species, when introduced or coming into contact in the midst of different environmental complexes.

In all of the experiments directed toward the solution of these problems cages of fine pearl-wire cloth, 22 meshes to the inch, have been used, with strong wire bottoms which completely prohibit all insectivorous enemies. The organisms employed are free from parasitic attacks and from the ravages of disease, so that the results coming from each culture represent the direct interaction of the organisms and the physical environment, the selective effect of predaceous organisms being totally eliminated. The results are further guarded by using only stocks whose traits are known for many generations, and these same stocks are further subjected to similar experiments in other complexes, so that the results can not be due to latencies or orthogenetic tendencies becoming actuated under the conditions of the experiment.

The plant for this investigation at Tucson now consists of 34 large cages and a large wire inclosure for pedigree cages, with the minor apparatus needed. Three locations at Tucson are utilized, which give different complexes in close proximity, yet with sufficient contrasts to make experimenta-



VARIABILITY OF LEPTINOTARSA MULTITÆNIATA WHEN TRANSPLANTED FROM ANCESTRAL HABITAT AT CHAPULTEPEC, D. F., MEXICO, TO TUCSON, ARIZONA.

tion profitable. 24 large cages and the inclosure for pedigree-work are located on the adobe soils of the Santa Cruz Wash at the foot of Tumamoc Hill; 8 cages are located on this hill near the laboratory and on the same level, and 3 in the gulch opening on the west side of the hill.

Eight species and races of Leptinotarsæ are now carried in these cultures at Tucson, in all 20 different cultures, which will hibernate during the winter of 1909-10. The conditions of the arid foresummer of 1909 retarded the growth of the food-plants and the breeding activities of the beetles, but the general progress of the series is considerably better than was anticipated even with favorable conditions.

Certain interesting results, partly new and in part confirmatory of general principles derived from my Mexican cultures, have been derived from these cultures of 1908-09. The behavior of newly introduced species and races continues to confirm the result stated in an earlier publication, that the response is immediate if at all, and that the introduced form does not remain suspended or uncertain in its behavior, but reacts at once in one way or another. This reaction may be equilibration with or without structural or physiological modification, or it may be extinction through inhibition of the reproductive powers, and only very rarely are the adults themselves eliminated by changed conditions.

A novel result was attained in cultures of two highly variable stocks of *Leptinotarsa multitæniata* and *L. oblongata,* wherein changed conditions of existence with large and strong populations gave decreased variability of a most striking kind. This was most remarkable in the highly variable species *L. multitæniata,* which was reduced to less than 15 per cent of the ancestral variability and the whole culture moved to a new mode and mean.

A series of experiments was begun at Tucson in 1908, in which *L. decemlineata* from Chicago, *L. multitæniata* from Mexico City, and *L. oblongata* from Cuernavaca, Mexico, which interbreed freely, were placed in a cage at Tucson. These species may be crossed with each other in pedigree cultures with results that may be interpreted to conform to the Mendelian law, if one so desires. They interbreed freely at the places mentioned, and out of the combination five forms result in the first hybrid generation: *L. oblongata* forms (A); *L. oblongata-decemlineata* forms (B) hybrid; *L. decemlineata* forms (C); *L. decemlineata-multitæniata* (D) forms hybrid intermediates; *L. multitæniata* forms (E). The three pure forms or dominant forms, A, C, and E contain pure matings and hybrid dominants. The intermediate forms B and D are clearly intermediate first-generation hybrids, but at Tucson the intermediate hybrid between *L. oblongata* and *L. multitæniata* does not appear. The cultures at this place gave the following in 1908-09; parent generation included 2 males and 2 females of the three species:

	A.	B.	C.	D.	E.
First generation	15	21	251	24	20
Males	2	2	6	3	3
Mated females	2	2	6	3	3
Second generation	0	7	495	3	0
Third generation*	0	1	94	6	0
Fourth generation	Not yet determined.				

* Sample count.

The behavior in this experiment, while differing in its result from that shown by similar cultures in Mexico, is the same in its general effect and shows clearly that two or more species may meet, interbreed, and produce through the combination a new species, or strain. The form C at Tucson is different from the pure *decemlineata* growing beside it under identical conditions. A, B, D, and E will have been eliminated from the cutlure at Tucson by the end of 1910, judging by the results of similar cultures made in Mexico.

Cultures of this kind are common in nature, allied migrating races meeting, and interbreeding with resulting combinations or extinction. In addition to the actual interbreeding effects there is the direct action of the physical and biological environment upon the process, and its products. Extended attention to this matter shows that the action of the biological environment has been enormously overestimated. Tests are being made of the action and importance of the physical environment in such cultures, preceding an attack upon the problems of internal relationships and processes.

In accordance with an agreement approved by the President Dr. MacDougal has accepted the title of honorary lecturer on heredity and evolution in the University of Arizona, and gave a course of four public lectures during the collegiate year of 1908-09. He has also given various addresses and lectures before associations and scientific societies and at the University of California, the University of Chicago, University of Missouri, Princeton University, Columbia University, Delaware Agricultural College, Stanford University, De Pauw University, Washburn College, Vassar Institute, and Brooklyn Institute of Arts and Sciences.

The Department is frequently requested to furnish living material of desert plants. Compliance with many of these requests would entail field trips of 15 to 30 miles and expenditures for transportation beyond the capacity of the Department. Such requests must therefore be largely turned over to commercial companies. The demand for photographic prints has also become so great as to make necessary that applicants be required to refund expenses of printing.

EQUIPMENT.

The Acclimatization Laboratory and grounds at Carmel, California, described on pages 58, 59 of this report, constitutes the most important accession to the facilities of the Department made during the year.

Some permanent improvements being necessary in the alluvial experimental tract near the Desert Laboratory, an area of 2.5 acres was purchased and a ruined adobe dwelling was restored, a concrete floor laid, and a roof of oiled dirt put on, to fit this structure for use as a special laboratory in connection with Professor Tower's work with the chrysomelid beetles and other acclimatization researches.

The development of the investigation of the reactions of the Leptinotarsæ and their food-plants to environmental stimuli has necessitated the construction of 30 additional vivaria in addition to a large working shelter, while the

series of lath shelters designed solely for the culture of plants has been extended.

Six balances, of the form known as silk scales, which had been recommended after trial by the Director of the Nutrition Laboratory, were acquired for use in the work on the water-balance of succulents.

Local transportation and delivery service having become a pressing matter, a second-hand gasoline runabout was purchased in New York and shipped to the Laboratory at the beginning of the year. The use of this machine during the busier seasons amounts to about 1,000 miles per month.

The wooden sailboat (by the aid of which three years' work was carried out on Salton Lake) having become unseaworthy, a motorboat designed by Mr. G. Sykes and built under his supervision in the shop of the Department was finished early in June and is now in commission. The hull is of steel, fitted with water-tight compartments, and supplies of gasoline and oil may be carried sufficient for the circumnavigation of the lake. This boat has shown good behavior in rough weather and gives an average speed of 6 miles per hour. In intervals between expeditions it is kept at the dock of the evaporation station of the U. S. Weather Bureau at Salton trestle.

The shop equipment has been brought to a high state of efficiency by the purchase of a number of tools, and by the careful setting and adjustment of the precision tools.

The additions to the equipment of the laboratories include thermographs, a new model solar radio-integrator, recording rain-gages, condensers, and many minor pieces of apparatus. A small model of an ice-machine (in which evaporation in a vacuum is reinforced by the absorbent action of sulphuric acid) has been found to be very efficient in cooling water for drinking and for use in the photographic dark-room at air-temperatures as high as 110° F.

THE STAFF.

Dr. Forrest Shreve spent the latter half of the year in Jamaica in the completion of some habitat studies and experimentation in transpiration begun in 1905.

Dr. J. E. Kirkwood, who was in residence at the Desert Laboratory from November, 1908, until July, 1909, in pursuance of his investigations on guayule. Dr. Kirkwood has since accepted the appointment of assistant professor of botany and forestry in the University of Montana.

Dr. B. E. Livingston, who has been a member of the staff at the Desert Laboratory since 1906, has accepted the appointment of professor of plant physiology in Johns Hopkins University, beginning his new duties October 1, 1909. Dr. Livingston retains his residence at Tucson and expects to spend a few months in 1910 in continuation of his researches upon evaporimetry, soil-moisture, and transpiration. An assistant will care for some of his experimental work in the interim.

Prof. V. M. Spalding, who has been a member of the staff at the Desert Laboratory since 1906, and who had begun some work there three years earlier, has followed his exhaustive treatise on the distributional movements of desert plants (Publication 113) through the press and has tendered his resignation to become effective January 1, 1910. Professor Spalding has accepted retirement under the terms of the Carnegie Foundation for the Advancement of Teaching, based upon his service for 28 years as an instructor and professor of botany in the University of Michigan and upon his service in this Institution noted above.

DEPARTMENT OF ECONOMICS AND SOCIOLOGY.*

HENRY W. FARNAM, CHAIRMAN.

As chairman of the Department of Economics and Sociology, I beg to submit the following report for the year ending September 30, 1909:

The past year has been a sad one for our Department, owing to the death of our Director, Dr. Carroll D. Wright, which occurred on the 20th of February. Colonel Wright was the originator and organizer of this department of work of the Carnegie Institution of Washington. It was through him that the group of collaborators was formed, and it was under his inspiration and guidance that the general plan of work was framed and put into operation. I may also add that his faith in its utility, his optimism, his wonderful power of enlisting the interest and cooperation of others have been of inestimable benefit to this Department from the beginning. His death was a double bereavement to us, inasmuch as it robbed us at once of our Director and of the head of the Division of Labor.

In view of the problems which arose in consequence of Colonel Wright's death, President Woodward invited the collaborators to meet for consultation regarding the future of the Department, in Washington, March 20, 1909. Full reports regarding the progress of the work of the various divisions were made at this conference, and at its conclusion the collaborators voted to recommend to the Executive Committee of the Carnegie Institution of Washington the appointment of the undersigned as chairman of the board. It was understood, and indeed requested, by the writer that he should not be called Director, but simply Chairman of the Board of Collaborators, that he should receive no salary, and that payments of expenses should be made through the office in Washington. This recommendation was accepted and ratified by the Executive Committee, April 19.

The collaborators also recommended that Prof. John R. Commons, of the University of Wisconsin, be appointed to carry on the work of the Division of Labor in the place of Colonel Wright. A more detailed account of what has been done in pursuance of this vote will be found under Division VIII.

The work of the several divisions has been prosecuted steadily during the past year, and the following summary statements are based upon detailed reports made to the chairman by the collaborators:

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*Address, Yale University, New Haven, Conn. (For previous reports see Year Books Nos. 3, 4, 5, 6, and 7.)

Division I.—POPULATION AND IMMIGRATION.

Prof. Walter F. Willcox takes, as his main theme, the History and Present Condition of the American Population, so far as its past and present have been investigated by the statistical method. The principal topics will be: (1) The growth of the population; (2) Elements affecting the growth of the population, such as births, deaths, marriage, immigration, etc.; (3) History of selected currents of immigrants.

A number of studies under the latter head have already been made, and Prof. H. P. Fairchild's study on "Greek Immigration" has been completed during the past year.

In earlier years eleven studies have been published and four completed but not published. The subject of French immigration to the United States is being investigated by Miss Louise Houghton, and it is expected that her study will be completed in a few months.

Dr. Willcox thinks that he could complete the writing of the book in a year, if he could give his time to it without interruption. The time which will be actually required will depend upon his ability to secure an extended leave of absence from Cornell University. In that case he would ask for leave of absence without salary and would feel obliged to draw from the allotment of his division about $4,500 for personal expenses and clerical help during that period.

Division II.—AGRICULTURE AND FORESTRY.

Dr. Kenyon L. Butterfield, president of the Massachusetts Agricultural College, is in charge of this large and important division. The general plan which he is pursuing is to divide the subject into eight sections, assigning each section to an expert, who in turn secures such assistance as he may need in studying different portions of his field. Reports of progress on these different parts of the work are as follows:

Prof. T. N. Carver, of Harvard University, is writing his chapter on "The economic characteristics of the agricultural industry," and hopes to have it finished before the end of the present academic year.

Prof. B. H. Hibbard, of Iowa State College, is still collecting material relating to the "Federal land policy." In studying State policies he is being assisted by Dr. John L. Coulter, who is at work on the "Land policy of North Dakota, South Dakota, and Minnesota;" by Miss Maud Ageton, who is studying Michigan; by Prof. F. G. Young, who is studying Oregon; by Miss Stella Hibbard, who is collecting material on Utah. Some work is also being done on Iowa.

Prof. H. C. Taylor, of the University of Wisconsin, has already secured a large number of studies relating to "Land tenure and the history of agricultural production in the United States." Thirteen of these were mentioned as

finished in the report for 1908. Of these, one, on the "Rise and decline of the wheat-growing industry in Wisconsin," by J. G. Thompson, has been published during the past year. During the same period a paper on "Agriculture in New England" has been presented by J. C. Marquis. The following are in preparation:

Land tenure in the United States, by H. C. Taylor.
Land tenure in Texas, by L. C. Gray.
The landlord's lien in the farm leases of the Northern States, by C. J. Foreman.
The history of agricultural production since 1840, by H. C. Taylor, J. L. Coulter, and L. C. Gray.

Dr. E. D. Jones, of Ann Arbor, who is dealing with the agricultural geography of the United States and the development of the agricultural market, reports progress.

Prof. F. W. Blackmar, of the University of Kansas, has completed and presented his study of "The irrigation and cultivation of arid America." This is an elaborate work of 376 typewritten pages, illustrated by 171 photographs and 30 maps. No arrangements have been made for its publication, because of certain questions which still have to be settled regarding the publication policy of this Department.

Division III.—MINING.

Mr. Edward W. Parker states that the original plan was to subdivide the work according to subjects, placing the preparation of the report on each important mineral product in the hands of an expert. Three such reports have been received and published privately, of which Professor Ries's "History of the clay-working industry," announced as received a year ago, has been published within the year by John Wiley & Sons. Four other manuscripts, as mentioned in the last report, are in hand but not yet published. The condition of the unfinished chapters is as follows:

"Iron ore" is in charge of Prof. C. K. Leith, of the University of Wisconsin, but as he has been absent all summer in the Hudson Bay region no recent report has been received from him.

"The history of the copper industry" is being treated by Mr. L. C. Graton, formerly in charge of the subject of copper for the United States Geological Survey, and now secretary of the Copper Producers' Association. This work is not yet finished.

"The history of the building-stone industry" is in charge of Dr. F. B. Laney, formerly of the University of North Carolina, now with the United States National Museum. Mr. Laney reports that he is making considerable progress and hopes to have his manuscript completed during the coming fall.

"The history of precious stones, abrasive materials, mica, and rare earths" is being studied by Dr. Joseph Hyde Platt, of the University of North Carolina. This work is well advanced and Dr. Platt hopes to complete the chapters before the end of the present calendar year.

"The history of chemical minerals," by Prof. Charles E. Munroe, George Washington University, is well advanced and that part of it relating to chemical minerals, including phosphate rock, will probably be finished during the present fall.

"The history of fluorspar, graphite, etc.," by Prof. Ira A. Williams, Iowa State College, Ames, Iowa, is making good progress and Professor Williams reports that the first draft of the manuscript of the chapters assigned to him is ready for final revision and editing.

"The history of mining law," by William E. Colby, of San Francisco, has been outlined, but is not yet finished. Mr. Colby is one of the chief assistants of Mr. Curtis H. Lindley, probably the greatest authority on mining law in the United States.

It will thus be seen that a considerable part of the work of this division is already in its final form.

Division IV.—MANUFACTURES.

Dr. Victor S. Clark reports that besides himself the following persons have been engaged upon this portion of the Economic History during the past year:

Prof. M. B. Hammond spent the summer of 1909 visiting libraries in the East, and in a trip through the manufacturing sections of the South, gathering material for a history of cotton manufactures.

Elmer A. Riley, of the University of Chicago, has prepared and presented a monograph upon the origin and growth of manufactures in the district of which Chicago is the immediate center.

Mr. I. P. Lippincott, Washington University, St. Louis, has completed and presented a monograph upon the history of manufactures in the central Mississippi Valley.

Mr. R. L. Douglas, of the State University of Kansas, has completed a monograph upon the history of manufactures in the western prairie States.

Mr. Julius Klein, of the State University of California, is just finishing a similar monograph upon the manufactures of California.

Dr. Francis Walker, of Washington, will prepare a history of prices of American manufactures in the nineteenth century, with a comparison of prices of secondary and primary manufactures and raw materials.

Dr. Clark has devoted practically all of his time for some seven or eight months of the past year to research work and to preparing some chapters of his final monograph. He has made a personal search for material in the public libraries of the United States as well as in the libraries of the British Museum and the Public Records Office in London. He has a considerable mass of typewritten notes and references, and the part dealing with the history of manufactures before 1815 is nearly ready for publication. Unfor-

tunately, his work will be interrupted for some time, on account of an appointment which he has accepted to take charge of the Territorial Census of Hawaii and to prepare the quinquennial report to Congress. He estimates that this work will occupy the greater part of his time for the coming year, but he has left his notes, papers, and other materials in Washington in charge of Dr. Francis Walker, who, as stated above, is to carry forward some investigations during Dr. Clark's absence.

Division V.—TRANSPORTATION.

Prof. B. H. Meyer, of the University of Wisconsin, states that the following papers have been published since the last report:

Railroad promotion and capitalization, by Cleveland and Powell, pp. xiv + 368. 1909.
Transportation and industrial development in the Middle West, by William F. Gephart, Ph. D., Columbia University Studies in History, Economics, and Public Law, vol. xxxiv, Nov., 1909. New York. pp. 274.
Railroad transportation in Texas, by Charles S. Potts, University of Texas, Bulletin No. 119, pp. 214.

Besides those mentioned above, nine monographs had been previously published and five completed but not published. The following eight are still unfinished:

History of the Illinois Central Railroad, by H. G. Brownson.
History of the granger movement, by Solon J. Buck.
Canadian railways in their relation to railways in the United States, by S. J. McLean.
Financial history of railroads, by F. A. Cleveland (vol. 2).
Transportation in the western cotton belt, by U. B. Phillips.
History of transportation on the Great Lakes, by Geo. G. Tunnell.
The development of transportation in California and the growth of the transcontinental business, by Allyn A. Young.
Development of transportation in the Pacific Northwest, by Frederick G. Young.

Division VI.—DOMESTIC AND FOREIGN COMMERCE.

Prof. Emory R. Johnson, of the University of Pennsylvania, reports that the following studies have been completed during the past year:

The foreign policy of the United States, by Dr. Albert S. Giesecke.
The foreign trade of the United States, Drs. S. and G. G. Huebner.

Dr. Thomas Conway, jr., is at work, with the aid of his sister, upon the "History of the coastwise commerce of the United States," which he hopes to complete by the end of the present year.

Professor Johnson has made some progress with the writing of that part of the history dealing with the period prior to 1789. He has secured a leave of absence from the University of Pennsylvania, to date from February 1, 1910, to the latter part of September of that year, and he hopes to give his entire time to writing the History of Commerce during that period.

Division VII.—MONEY AND BANKING.

Prof. Davis R. Dewey, of the Massachusetts Institute of Technology, gives the following report regarding the progress of work on the part of his assistants. The following are titles of studies completed but not published during the past year:

Banking in Oregon, by J. H. Gilbert, University of Oregon, Eugene, Oregon.
History of banking in Wisconsin, by R. H. Hess, University of Wisconsin, Madison, Wisconsin.
History of banking in Ohio, by C. C. Huntington, Bureau of Corporations, Washington, District of Columbia.
History of early banking in Missouri, by J. E. Pope, University of Missouri, Columbia, Missouri.
History of banking in North Carolina, by C. L. Raper, University of North Carolina, Chapel Hill, North Carolina.
History of banking in Alabama, by W. O. Scroggs, Harvard University, Cambridge, Massachusetts.
History of banking in Tennessee, by St. G. L. Sioussat, University of the South, Sewanee, Tennessee.
History of banking in Illinois, by R. J. Sprague, University of Maine, Orono, Maine (in part).

The following are unfinished:

Relation of the Treasury to the New York money market, by J. W. Crook, Amherst, Massachusetts.
Banking in Kentucky, by Elmer C. Griffith, University of Chicago, Chicago, Illinois.
History of the national banking system, by G. D. Hancock, University of Wisconsin, Madison, Wisconsin.
History of banking in Louisiana, by T. H. Jack, Harvard University, Cambridge, Massachusetts.
History of banking in Iowa, by I. A. Loos, State University of Iowa, Iowa City, Iowa.
History of banking in California, by R. Lowry, Oakland, California.
Relation of the crop movement to the money market in the West, by F. L. McVey, President of the University of North Dakota.
Banking in Indiana, by R. M. Milburn, Jaspar, Indiana.
Bank and trust company legislation, by J. B. Phillips, University of Colorado, Boulder, Colorado.
History of the greenback movement in Iowa and the Northwest, by C. C. Ruggles, State University of Iowa, Iowa City, Iowa.

Professor Dewey has been engaged during the summer in the preparation of a study on "Banking practices under the early State charters," which will be published by the Monetary Commission. He also has the general supervision of the preparation of a monograph on "The first United States bank," by Dr. John T. Holdsworth, now of the University of Pittsburg, and of "A history of the safety fund system of New York," by Robert E. Chaddock, of Columbia University.

These monographs are in type and will be published soon, without financial aid from the Carnegie Institution of Washington.

Professor Dewey feels very much encouraged by the progress recently made and he hopes to have the work substantially finished by the end of the next year.

Division VIII.—LABOR MOVEMENT.

In accordance with the recommendation of the Board of Collaborators, Prof. John R. Commons was invited by the Executive Committee of the Carnegie Institution of Washington to take charge of this Division upon the death of Colonel Wright. Colonel Wright had already arranged with Professor Commons and his assistants to prepare several studies for him. In addition to this he had made an appropriation of $1,500 to be used by Professor Commons in the collection of material relating to the labor movement, as stated in his annual reports for 1907 and 1908. This appropriation was made on the condition that the more valuable part of this material, which had been gathered for the Bureau of Industrial Research, should be printed as a documentary history of labor in the United States. The material turned out to be very extensive. The two volumes originally contemplated have now grown to six dealing specifically with the labor movement, while two more deal with labor conspiracy cases between 1806 and 1842. Two other volumes relating to the plantation and the frontier are included in the same series and the ten volumes are to be issued by the Arthur H. Clark Company, of Cleveland, Ohio, in the course of the ten months beginning September, 1909.

While it seemed eminently desirable to secure the cooperation of Professor Commons in the work of the Carnegie Institution of Washington on account both of the amount of study which he had already put upon the subject of labor and of the appreciation of this work shown by Colonel Wright, the situation was a difficult one from the fact that his investigations had been originally undertaken for the Bureau of Industrial Research, which had spent a much larger sum upon them than that contributed by the Carnegie Institution of Washington. The writer accordingly visited Madison in April and discussed the situation at length with Professors Commons and Ely. As a result a tentative plan was agreed upon, according to which Professor Commons should take charge of the Division of Labor for the Carnegie Institution of Washington and complete the work begun by Colonel Wright, but have the privilege of publishing his history as a part of the History of Industrial Democracy, undertaken by the Bureau of Industrial Research, as well as in the series contemplated by the Carnegie Institution of Washington, each organization receiving credit for its share in the final work. In order to carry this plan into effect it was necessary to secure the consent of the contributors to the Bureau of Industrial Research as well as of the Carnegie Institution of Washington, and certain financial questions have arisen which have thus far made it impossible to reach a final agreement. It is hoped, however, that in the course of a month the matter will be settled to the satisfaction of all parties. While in general such a partnership as that described is not an ideal arrangement, the peculiar circumstances of the case made it seem the best solution of the problem which arose on the death of Colonel Wright.

Apart from the "Documentary history of labor" and from the monographs which were to have been prepared by Professor Commons and his assistants, but which will be merged in his larger work in case he assumes charge of this division, the following topics are still being studied under arrangements made by Colonel Wright:

Labor in the cotton industry, by Prof. M. B. Hammond, who is also studying the cotton industry for the Division of Manufactures.
Labor history of California, by Prof. Ira B. Cross.

Division IX.—INDUSTRIAL ORGANIZATION.

Prof. Jeremiah W. Jenks, of Cornell University, has temporarily suspended advanced work in order to await the reports of some other divisions which cover in part the ground assigned to him, thus avoiding duplication of labor and needless expense. This necessitates a certain delay on his part. In the meantime Prof. Horace L. Wilgus, of Ann Arbor, is continuing his work on "The history of corporation law."

Division X.—SOCIAL LEGISLATION.

This division is in charge of H. W. Farnam, and during the past year the following monographs have been received:

The labor legislation of Indiana, by Charles F. Austin.
Recent labor legislation in Massachusetts, by Prof. F. S. Baldwin.
The labor legislation of Kansas, by Prof. S. E. W. Bedford.
The labor legislation of Iowa, by E. H. Downey.
The mountain whites and social legislation, by Prof. G. W. Dyer.
The poor law of Ohio, by Prof. J. E. Hagerty (in part).
The poor legislation of Michigan, by Carl E. Parry.
The poor law and public relief in Missouri, by Prof. T. J. Riley.
Homestead and exemption laws in the Northern States, by Prof. J. H. Underwood.
Educational land grants of North Dakota, by Dr. John L. Coulter.
Labor legislation of New Jersey, by Dr. A. S. Field.
Labor legislation of Maryland, by H. Wirt Steele (in part).
Social policy of the American colonies, by Prof. Clive Day. (Professor Day's study is to constitute the introductory chapter of the final volume of this division.)
The labor legislation of California, by Miss Lucille Eaves.

Mr. D. L. Peacock has presented a study of the mining laws of the Southern States and has made progress on his study of the labor and rural credit policy in the Southern States.

The following studies are in course of preparation:

Mechanics' lien laws of the United States, by W. L. Bailey.
Educational land grants of Wisconsin and South Dakota, by Dr. John L. Coulter.
The land legislation of Texas, by R. McKitrick.
The mining laws of Pennsylvania, by Blaine F. Moore.
Anti-trust legislation in Wisconsin, Nebraska, Iowa, and Minnesota, by C. L. Waldron.

Mr. Farnam has been prevented by pressure of other work from putting as much time on the preparation of his volume as he had expected, but he hopes to be able to make more progress during the coming winter.

Division XI.—FEDERAL AND STATE FINANCE, INCLUDING TAXATION.

Prof. Henry B. Gardner, of Brown University, like many other collaborators, finds it very difficult to secure sufficient time for the work of the Carnegie Institution of Washington on account of the pressure of academic duties. He hopes, when his preliminary studies are in, to take a leave of absence, which will enable him to devote himself for some time to the work of completing his volume. The following list shows the present status of the subsidiary studies which are being made for this division:

Completed during the past year, but not published:

History of clergy taxes and quit rents in Maryland, by Prof. Beverley W. Bond, jr., Purdue University, Lafayette, Indiana.

Studies in process of completion:

Financial history of California, by Prof. Carl C. Plehn, University of California, Berkeley, California. According to the latest report from Professor Plehn, this work is well advanced towards completion, but Professor Plehn has gone to Europe for a year.

Financial history of Connecticut. This was undertaken by Prof. Fred R. Fairchild, of Yale University, but Professor Fairchild has given it up on account of other investigation work and has turned it over to Mr. Henry F. Walradt, a student at Yale, who will use the results of his study as a thesis for his doctor's degree in June, 1910.

Comparative study of the financial development of certain of the larger cities of the country, by Oliver C. Lockhart, Ohio State University. A part of this work has been submitted, and Mr. Lockhart expects to complete the first draft of the remaining chapters this autumn, although he doubts if he succeeds in completing the whole study before next summer.

Financial history of Indiana, by Prof. W. A. Rawles, Indiana University. Professor Rawles is working on this study and will finish it as soon as possible, but does not see any immediate prospect of completing it.

Financial history of Iowa, by Prof. Frank I. Herriott, Drake University.

License taxes of Southern States, by Prof. H. A. Millis, Leland Stanford Jr. University, California. Professor Millis had hoped to complete this study before this, but was delayed by other work and can not now complete it before July or August, 1910.

Financial history of New Jersey, by Edgar Dawson, Princeton University, Princeton, New Jersey. Mr. Dawson has been obliged to put this work off until the summer of 1910.

Financial history of Ohio, by Prof. E. L. Bogart, Princeton University, Princeton, New Jersey. Professor Bogart has this work well along, and expected to complete it this summer, but has had to postpone it on account of other work.

Financial history of South Carolina, by Mr. George McCutchen, instructor in the University of South Carolina. Mr. McCutchen hopes to complete his study this year.

Financial history of Texas, by Mr. E. T. Miller, formerly an instructor in the University of Texas, now a graduate student at Harvard. Mr. Miller expects to complete this work this autumn.

Financial history of Alabama, by William O. Scroggs, a graduate student at Harvard. Mr. Scroggs's work is well advanced toward completion, and he expects to finish it soon.

Financial history of Tennessee, by Prof. St. George L. Sioussat, University of the South. Professor Sioussat reports that the investigation for this study is finished and only the typewriting of it remains to be done.

Financial history of Virginia, by Mr. Edgar Sydenstricker, graduate student at the University of Chicago. Mr. Sydenstricker's study is complete in part.

Financial history of Illinois, by Prof. N. A. Weston, University of Illinois. Professor Weston has had his seminary working on this study. He has sent several papers dealing with special topics, and expects to continue the work the coming year, but can not say definitely when it will be completed.

Financial history of Vermont, by Dr. Frederick A. Wood (author of the study of taxation in Vermont in the Columbia University Studies). Mr. Wood has practically completed this study, except for the copying.

Financial history of Minnesota, by Dr. R. V. Phelan, University of Minnesota. Dr. Phelan has just completed this work.

Professor Gardner has also employed for fifteen months past Miss Lorian P. Jefferson, a graduate student at the University of Wisconsin, who has made a very thorough examination of the material, other than public documents, bearing on the financial history of the United States, in the most important libraries east of the Mississippi and in Missouri.

Division XII.—THE NEGRO IN SLAVERY AND FREEDOM.

The work of this division has been interrupted during the past year by unforeseen circumstances. Mr. Alfred H. Stone, who has charge of this topic and who had already made gratifying progress with it, found himself obliged, on account of the ravages of the cotton boll weevil, to suspend literary work in the spring of the present year and devote himself for a time to the warfare against this pest, which has already done so much damage to the country at large, and which seriously threatened investments in Mississippi, on the income from which Mr. Stone was relying to pursue his scientific work. Mr. Stone is one of those who have not asked for or received any compensation for their services, and this interruption, while primarily made for the purpose of protecting his business interests, will ultimately, we hope, contribute toward the advancement of his work for the Carnegie Institution of Washington.

The plan which Mr. Stone blocked out in the beginning was to embody the results of his work in three volumes, each covering a period in the history of the American negro, but each complete in itself. The first volume was to extend from the introduction of negro slaves into the East Indies down to the invention of the cotton gin; that is, from 1501 to 1793. The second volume was to cover the history of the negro in slavery, from 1793 to 1861. The third volume was to treat of the economic history of the race under freedom. Most of the material for volume 1 has been gathered, and the actual writing of the volume commenced. Mr. Stone hopes to complete it during 1910. Much of the material for the two later volumes has also been gathered, and Mr. Stone intends to devote all of the time that he can spare from necessary business demands to the completion of the work.

INDEX OF STATE DOCUMENTS.

This work, which is under the supervision of a special bibliographical committee, consisting of Professors Henry B. Gardner, Walter F. Willcox, and Davis R. Dewey, is being carried forward energetically by Miss Adelaide R. Hasse, of the New York Public Library. In addition to the volumes for Maine, New Hampshire, Vermont, Rhode Island, New York, and Massachu-

setts, which were issued at the time of the last annual report, volumes have now been completed for California and Illinois. These volumes, which are handsomely printed in quarto, are published by the Carnegie Institution of Washington directly and are the only part of the work of the Department of Economics and Sociology which the Institution has thus far published.

The sum originally appropriated by the Trustees for this index was $17,500. This sum is now nearly exhausted. It was impossible at the beginning to anticipate the mass of material that would be involved, and, therefore, to estimate the amount of money required to print it. It is believed, however, that the work is of great importance to scholars, since it constitues practically the only available general index to state documents. It is hoped that the Trustees will find it possible, by making an additional appropriation, to insure the completion of this important undertaking.

The readjustments necessitated by the death of Colonel Wright make it desirable at this time to review the past and consider the outlook for the future. When the Department of Economics and Sociology was organized, in the latter part of 1903, an annual appropriation of $30,000 was made by the Carnegie Institution of Washington to continue through a period of five years, making the total appropriation for this object $150,000. In 1905 an additional appropriation of $17,500 was made for the preparation of the Index to State Documents, and an allowance for interest has since then brought the total credit of this Department up to $167,758.48; of this total, $114,450.36 had been drawn down to September 30, leaving a balance of $53,308.12.

The field was originally divided into eleven divisions. These were increased to twelve in 1906 by the addition of a division for the Negro in Slavery and Freedom, while the Index virtually constitutes a thirteenth division. Though the appropriation was originally made to continue through five years, no definite estimate was made with regard to the time needed. It is clear that in so large an undertaking no exact estimates could be made; and, in his report of three years ago, Colonel Wright stated that the time might be longer than at first anticipated. It should, therefore, excite no surprise that the work is not yet finished.

The undertaking has proved to be an exceedingly difficult one. Our country covers an area about equal to that of the whole of Europe. It represents extremes of climate, of natural resources, of social conditions. As far as its economic history is influenced by law, and this is particularly the case in the divisions of Finance, of Money and Banking, and of Social Legislation, the situation is very complex. Apart from the Congress of the United States, we have legislative bodies in forty-six States and two Territories, exclusive of Alaska and Hawaii. Europe, including San Marino, Monaco, and Andorra, only contains at the present day 27 sovereignties. Our economic history is more the history of a continent than of a single state.

Not only is the field a vast one, but the workers in it are comparatively few. Before 1880 we had barely a handful of trained economists in the United States. The popularity of the study of economics, the rapidly increasing call for teachers on the part of the universities and colleges, the need of experts on the part of the Government and of various private enterprises, have created a demand for economists which has thus far been inadequately met. It has been consequently impossible to secure the exclusive services of workers in this field. Of the twelve collaborators, including Colonel Wright, eight are college professors or college presidents and two hold Government offices. All have prior demands upon their time. The only two who have been free in the past to give their time to the work are obliged to consider the importance of deriving a living income from other sources. Both of them are drawn away from the work of the Institution during the present year, the one in order to fill a temporary Government position, the other in order to look after business interests.

It will be seen from the statements made on behalf of several of the collaborators that many of the men engaged in teaching find it necessary to secure a leave of absence from the institution with which they are connected in order to bring the work of the Carnegie Institution of Washington to a conclusion.

In a separate report made at the request of the Executive Committee, it was pointed out that none of the collaborators had drawn from the Carnegie Institution of Washington for personal services anything that could be fairly considered a compensation for his work. Some have drawn nothing at all; the largest sum drawn by any individual averages a little over $500 a year. They have undertaken the work on account of their interest in the subject, devoting to it such time as they could spare during the vacation or at odd times, and have endeavored to put as much as possible of the appropriation into securing preliminary investigations. Even these have been, in most cases, prepared without any adequate payment. In many cases such studies have been made by graduate students who were working for their doctor's degree, and who received from the Carnegie Institution of Washington only enough to cover the additional expense, mainly for travel, incurred in consequence of taking up a thesis subject assigned by us.

In spite of these difficulties, a large amount of preparatory work has been done. The writer is compiling a bibliography of the studies, both published and unpublished, which have been made under this grant. The task is not an easy one, and exact figures can not be given until after some verifications; but apart from the eight large volumes of the Index to State Documents, we have secured the preparation of about 130 elaborate monographs and books, in addition to a number of shorter articles. Between 60 and 70 are still in course of preparation. Thus the greater part of the preparatory work is now done. In the case of several of the divisions, a considerable part of the final

work is written. It will be noticed that the plan pursued has not been uniform in all of the divisions. In two it seemed best to the collaborator to divide his subject into chapters or sections and to assign each section to an expert for completion. The final volumes of these divisions will, therefore, be made up of contributions written by different authors. The other collaborators have pursued the plan of securing preliminary studies on certain topics, but expect to write the final volumes themselves. It may be two or three years before all of this work can be completed, but it is hoped that several of the volumes will be finished before that time.

Whether or not an additional appropriation will be necessary can not be stated definitely at present. One collaborator has expressed his intention to complete the work of his division at his own expense, if the allotment should prove insufficient. Some divisions may possibly require less than the allotment, in which case there will be a surplus that can be assigned to other divisions. It is also hoped that a part of the sum set aside for administration purposes will be used for investigation, now that the Department is relieved of the salary of a Director. After making all allowances for these economies, the writer thinks it not improbable that to complete the whole of the work some additional money will be needed, though he is not able to specify the amount, and though he will make every effort to keep the expenditures down. In any case, the Index, as distinguished from the contributions to the Economic History, will need more money, as explained above.

The total amount which the Institution will be ultimately obliged to spend depends to a large extent upon the policy which it pursues with regard to publications. No appropriation has yet been made for this purpose. As our Department contains twelve divisions, the entire work when finished will comprise at least twelve volumes, but some of the collaborators contemplate two or three volumes for their own division, and we must therefore consider the possibility of twenty-four volumes instead of twelve. It is believed that the work will have sufficient interest to be taken up on a commercial basis by some publisher. If this should prove feasible and if the Carnegie Institution of Washington should give its consent, it would be relieved of a large expense for printing, which was doubtless anticipated in the beginning, though not specifically provided for. In view of the great importance of the work and of the economy exercised by the collaborators in carrying it out, it is hoped that the Institution will find itself able to make additional grants should they prove necessary. In the meantime we intend to do our best to complete the work with the funds in hand.

DEPARTMENT OF EXPERIMENTAL EVOLUTION.*

C. B. Davenport, Director.

The President of the Institution has suggested that in estimating the work of departments the unit should not be the year but the decade. It is now half a decade since work at the Station for Experimental Evolution was started, and this may be regarded as an opportune time for considering what this Station has accomplished and what may fairly be expected by the end of the first decade.

At the outset the investigators at this Station had not had extensive experience in breeding-work. Little such work was then done in scientific laboratories or departments of universities. A year or two was required to gain experience, but work rapidly increased to the maximum that each was able to handle properly. The material under observation and experimentation has included mammals (cats, sheep, goats), birds (poultry, canaries and other finches), fishes (to a very limited extent, with the cooperation of the State fish-hatchery), insects (including beetles, Lepidoptera, and flies), and flowering plants in great number. An extensive body of technical experience in the proper method of breeding these organisms has been acquired.

The problem of the "origin of species" has taken on quite a new form in the half-century since Darwin's epoch-making work appeared. Formerly individuals were thought of as a whole and the attempt was made to arrange them in varieties, species, genera, and so on. The basis of classification was, indeed, the possession of one or more common characteristics of form or function, but the characteristic was thought of merely as a convenient incident, of interest chiefly to the classifier. Today we clearly recognize that the whole problem of evolution is the problem of origin, nature, and relations of characteristics. The production of a new "species" is the production of a new characteristic; not necessarily new to nature, but in a new combination. He who by hybridization makes a new combination of characteristics that breeds true makes a new species, as truly as he who induces by physical or chemical means a characteristic that is both new to the species and breeds true. The difference in the two cases rests largely on the origin or source of the characteristic in the two cases.

Since characteristics are of primary importance in evolution, it is the business of this Station to consider them from all aspects, attention at present being directed principally to the following subjects:

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* Situated at Cold Spring Harbor, Long Island, New York. Grant No. 538. $29,000 for investigations and maintenance. (For previous reports see Year Books Nos. 3, 4, 5, 6, and 7.)

THE ORIGIN OF CHARACTERISTICS.

Work on this topic involves the ability to produce them by changing the physical and chemical environment; but it also includes observing the conditions under which they arise "spontaneously" or by mutation. Data concerning the origin of characertistics have been acquired in the course of our studies. Several new qualities have arisen suddenly and *de novo* from parents of well-known pedigree, such as poultry with short mandibles, combless birds, birds lacking one toe on each foot, with two toe-nails to a digit, with no nail, without one or both wings, and without a tail. All of these new characters, excepting two that were not tested, were permanent acquisitions of the germ-plasm. Our associate, Prof. W. L. Tower, has tried, with much success, to control the origin of new characteristics in the Colorado potato-beetle and its allies. His results have been published in his work* "Evolution in Chrysomelid beetles of the Genus Leptinotarsa." In high temperature and dry air the germ-plasm of this beetle produced less pigment; in other cases it gave rise to an increased number of generations in the reproductive cycle, and was otherwise modified. For the immediate future we have planned a series of studies on the effect of cave conditions in modifying characteristics, to be in charge of Dr. A. M. Banta, who will become a resident investigator at this Station.

THE CHEMICAL BASIS OF CHARACTERISTICS.

In my last report I mentioned the discoveries of chemical differences in the proteins and hemoglobins of closely related species. There are strong theoretical reasons for believing that differences in the adult are determined by chemical differences in the egg. These chemical characteristics lie at the bottom of the morphological and physiological characteristics. During the past year we have sought to determine the chemical differences between the dominant white and the recessive white of poultry plumage. Dr. W. J. Gies, of New York City, was interested in the problem and undertook the determination upon pedigreed material supplied from this Station. Dr. Gies has not yet reported fully, but there is reason for suspecting that a chemical difference exists in the feather of the two kinds of whites.

The number of problems of a chemical nature that have been opened by the breeding work has rendered advisable the appointment of a physiological chemist, and Dr. R. A. Gortner, a recent graduate of the department of physiological chemistry at Columbia University, entered upon this work September 1, 1909.

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* W. L. Tower: An investigation of Evolution in Chrysomelid Beetles of the Genus Leptinotarsa. Publication No. 48 of the Carnegie Institution of Washington.

THE ONTOGENESIS OF CHARACTERISTICS.

While each transmissible character of the organism is latent in the germ, during ontogeny it gradually becomes potent and eventually acquires its adult condition. Since the germinal determiner bears no resemblance to the completed characteristic, there must be a series of fundamental changes in ontogeny. We know that the course of ontogenesis varies according as the germinal "determiner" comes from both parents or one only. In the latter case the characteristic (technically denominated heterozygous) is weakened and often remains at a low stage of development, even in the adult. Such heterozygous characters show how ontogenesis is controlled by heredity. In our publications we have repeatedly proved that heterozygous organs tend to remain at a low or incomplete stage of development, in consequence of which they sometimes, on the one hand, exhibit peculiar forms and, on the other, obscure the Mendelian proportions in transmission. Many of these heterozygous forms can be fully interpreted only by embryological studies.

Again, many organs show themselves, in transmission, to be complex—composed of several unit-characters or factors. It is probable that an interpretation of this peculiar behavior will be given by embryological studies. Arrangements have been made with Prof. F. R. Lillie, of the University of Chicago, by which he is furnishing a trained student to work upon the development of some of the hybrid organs of our pedigreed stock. In accordance with this arrangement Mr. J. C. Stevenson is at present resident at this Station and studying the developmental history of the heterozygous combs of poultry.

THE TRANSMISSION OF CHARACTERISTICS.

This is the phase of the study upon which most work has been done. The results have been published in a series of papers, a list of the more important of which is given below. Our results, so far as published, constitute a satisfactory part of the history of the remarkable development of our knowledge of this subject for which the present decade will ever be famous. A brief statement of the titles of the papers published by the different workers in this field will give an idea of the ground covered.

By the Director: Black sheep in the flock. Imperfection of Mendelian dominance in poultry hybrids. Inheritance in poultry. Heredity and Mendel's law. Dominance of characteristics in poultry. Determinance of dominance. Inheritance in canaries. Eye-color in man. Hair-form in man. Hair-color in man. Inheritance of characteristics in poultry.

By Dr. Shull: Latent characters in a white bean. Significance of latent characters. Variations in the *Oenotheras*. The pedigree culture. Mendelian inheritance. Branching and disk color of sunflowers. Flower color in *Lychnis* and the mullein. A new Mendelian ratio and several types of latency. The composition of a field of maize. A pure-line method in corn breeding. The "presence and absence" hypothesis. *Bursa bursa-pastoris* and *Bursa heegeri*, biotypes and hybrids. A simple chemical device to illustrate Mendelian inheritance.

By Dr. Lutz: The tegminal position in *Gryllus*. Inheritance of variations in the color pattern of *Crioceris*. Variation and correlation of characters of *Gryllus*. Inheritance of the manner of clasping the hands. Combination of alternative and blending inheritance.

By Mr. R. H. Johnson: Evolution in the lady-bird beetles.

In addition, our associate, Dr. W. E. Castle, at Harvard University, has published alone or with students papers on results of investigations on—

Heredity of coat characters in guinea-pigs and rabbits. Heredity of hair-length in guinea-pigs, and its bearing on the theory of pure gametes. Color varieties of the rabbit and other rodents, their origin and inheritance. Reversion induced by cross-breeding and fixation. Selection and cross-breeding in relation to the inheritance of coat-pigments and coat-patterns in rats and guinea-pigs. Studies in inheritance in ear-size, weight, skeletal dimensions, and color of rabbits.

It is impossible to state in a few words the chief results of these varied contributions. In the main they have demonstrated the wide application of the Mendelian principles of inheritance to the characteristics of animals and plants, both domesticated and feral. They have silenced the objection that the Mendelian phenomena related only to "artificial" varieties and proved that they hold equally for species in nature. They have thoroughly analyzed, for the first time, the phenomena of dominance in transmission, and have shown its wide fluctuation from perfection to an impotency such that apparently there is no transmission. They have introduced the idea of the dominance of the more-developed characteristics over the less-developed, and have extended the ideas that while the absence of a characteristic is recessive to presence, the characteristic itself may be an inhibiting factor. They have shown the composition of many color-characteristics out of several factors, revealing a hitherto unsuspected complexity of the germ-plasm. They have, on the other hand, dealt with certain cases, particularly in insects and oenotheras, where segregation of characters seems not to occur.

Finally, this Station has collected and begun to publish studies on data relating to inheritance of human qualities. Eye-color, hair-color, and hair-form have been by us first demonstrated to behave in Mendelian fashion and to be predictable in the offspring. In cooperation with the Committee of Eugenics of the American Breeders' Association the work of gathering data concerning the transmission of human characteristics goes on apace.

Studies have been undertaken on the mechanism of heredity, which is currently thought to reside in the stainable bodies (chromosomes) of the germ-cells. Miss Lutz has organized a series of critical studies which will, it is expected, answer definitely the question whether the determiners of characteristics are carried exclusively in the chromosomes.

THE MODIFICATION OF CHARACTERISTICS.

By changed environmental conditions characteristics may, of course, be changed and the modifications, though usually somatic only, are sometimes transmissible (Tower). By selective breeding, characteristics may be modi-

fied, increased, or diminished, and there is evidence that such modifications are sometimes inherited. Thus Castle has shown that the extent of the pigmented area in rats may be varied in an inheritable fashion by selection of slight variations and, beginning with a scarcely recognizable trace of syndactylism, I have succeeded in getting very exaggerated forms of this condition. On the other hand attempts, in other cases, to increase or diminish characteristics (*i. e.*, certain color-characters) by selection have not yet met with success. This whole subject of the modifiability (and particularly the inheritable modifiability) of characters deserves thorough investigation. Here lies the crux of the controversy between the Darwinian "selectionists" and the De Vriesian mutationists.

Of great importance in this regard is the question whether the soma can modify the germ-plasm in a detailed way. Guthrie, two years ago, adduced evidence for this view, but his results have not been confirmed either subsequently in his own publications nor by Dr. Castle working with rats. We are making experiments with poultry that should test this doubtful matter thoroughly.

Meanwhile we are extending our knowledge of the extent of modification that characteristics undergo in nature, Drs. Harris and Shull and R. H. Johnson and W. L. Tower having obtained extensive series of data from various species of plants and insects. These studies, as well as those on selection, lend support, in many cases, to the view that natural characteristics in a state of nature undergo a progressive change in a definite direction. Evolution is proceeding in consequence of internal changes in the germ-plasm that are doubtless controlled by external conditions.

Extensive studies on the effect of external, particularly nutritive, conditions on the development of the form and structure of plants were begun by Dr. E. F. Transeau at this Station, but they have not yet been reported on. The results of starvation or semistarvation were very marked.

THE RELATIONS OF CHARACTERISTICS.

In any organism characters do not exist alone but are related to other characters and to the external world. This fact is the basis of the phenomena of correlation of characters and of the elimination of unfit characters by the selective annihilation of individuals carrying them. We have seen how the whites and the solid black of poultry make them conspicuous and especially liable to be killed by crows. Dr. Harris has published accounts of a series of observations directed toward determining whether the eliminated differ in a given particular from the surviving. The results are usually negative, for the characters considered.

This is, then, the situation in which this Station finds itself at the end of the first half-decade. The attack on the problem of the organic characteristic

is well begun. This attack is being made from six sides—the origination of the character, its chemical basis in the germ-plasm, its ontogenetic development, its modifiability, its transmissibility, and its relations to the other characters and to the external world.

CHANGES IN STAFF.

While stability in the resident staff is to be nominally sought for in dealing with problems involving the long-continued breeding of strains of animals and plants, yet a not unimportant part of the work of the Station must be for some years, until the work is more generally introduced into universities, to train young men for positions elsewhere. Dr. Lutz, resident investigator since the beginning of the Station, received and accepted, early in the calendar year, a call to the American Museum of Natural History in New York City, where he will take part in making collections and installing exhibits illustrating evolutionary principles. Owing to the proximity of Dr. Lutz in his new position to the Station, his experiments were continued here for several months under his supervision and, by agreement with the direction of the museum, his work on heredity of fruit-flies will be continued there.

The place vacated by Dr. Lutz has been filled by Dr. R. A. Gortner, referred to in the general part of this report, who will help answer some of the chemical questions that arise in all experiments on the heredity of color-characteristics. The vacancy made by the resignation of Mr. R. H. Johnson has been filled by the appointment of Dr. Arthur M. Banta, professor of biology at Marietta College, formerly a student of Prof. Carl H. Eigenmann, under whose stimulus he began and completed an extensive study of the "Fauna of Mayfield's Cave" (Publication No. 67 of the Carnegie Institution of Washington). Dr. Banta will, as stated above, devote himself to a study of the modifying influence of cave conditions upon organisms. Valuable results are to be anticipated from such an experimental study, since, in nature, cave life is associated with striking modifications, such as loss of pigment, loss of sight, and elongation of antennæ. Such studies were anticipated at the time the main building was erected but have hitherto not been carried on, awaiting the appearance of a properly equipped investigator.

DETAILED REPORTS ON SCIENTIFIC WORK.

WORK ON ANIMALS.

Poultry.—In this work 55 pens were maintained and 3,005 chicks hatched. One of the vivaria was used for indoor brooding with success. Four fireless brooders were purchased and found to be superior for our purpose over the heated brooders, while their care and expense of maintenance was much less. Two matings were made between white and pearl guinea-fowl. All offspring were of "pearl" color except that they were mottled with large white patches

on belly and primaries. This year the mottled birds were bred together and produced almost exactly one-fourth white birds. The black pigmentation is dominant over its absence, but in the heterozygote does not develop on the belly and the feathers of the extremity of the hand.

Finches.—The breeding of these birds was in some respects more successful than last year, 148 having been reared, an increase of 48 per cent. This success was chiefly due to a slight alteration of the heating system and better night firing.

Sheep and Goats.—Thirteen sheep and six goats were reared in the various matings. Cooperative work in sheep-breeding has been begun with the New Hampshire Agricultural Experiment Station.

Cats.—In October, 1908, a new cat-house of concrete blocks was erected, giving four compartments for breeding cats and four for mothers with young. The health of the cats was greatly improved, but they have shown a large degree of sterility in confinement. Nine young were born in the spring.

Insects.—Dr. Lutz reports as follows:

From September 1, 1908, to March 1, 1909, the work with *Drosophila* was continued along the same lines as in previous years. Considerable breeding was also done with *Gryllus,* in the greenhouse, in order to continue the long-winged strain brought from Mexico and to cross it with our native crickets. Having accepted a position with the American Museum of Natural History, the work with *Drosophila* has been continued there with some slight modification, and a report is now being prepared upon the greater part of it. Through the kindness of the Station the crickets were kept for me at Cold Spring Harbor until the middle of July, 1909. The strains are now being kept at the museum for use in future work, and it is hoped that a report upon the work done with them at the Station will be ready shortly.

WORK ON PLANTS.

Dr. Shull, upon his return from his European trip, continued his study of Mr. Burbank's horticultural methods and results, and in the limited time at his disposal at the Station continued the strains of plants upon which he has been at work for the last few years. He reports as follows:

In the pedigree studies of plants attention has been mainly given, as in the past several years, to the range of applicability of such recently developed conceptions of variation and heredity as are involved in the words "mutation," "biotype," "segregation," "unit-characters," "fluctuation," "regression," etc. The cultures have been in unusually good condition, except those of *Helianthus* and *Verbascum,* and a small portion of the *Lychnis* cultures which were taken to a plot of ground at some distance from the Station, which had not been sufficiently fertilized. The effect of this was that the branching which is being investigated in *Helianthus* was very much reduced, very few of the *Verbascums* reached maturity the first season, and the *Lychnis* remained small and bore relatively few flowers, so that the time within which observations could be made upon them was much limited.

The cultures of Indian corn were somewhat enlarged to allow a fuller test of the relative vigor of pure-bred types and their hybrids. The results have been consistent throughout, the self-fertilized families appearing to have reached a certain low state of vigor which is not further decreased by continued self-fertilization. Crossing between individuals belonging to a single pure type appears to give no advantage over self-fertilization, while all crosses between individuals belonging to distinct types are of superior vigor.

In Shirley poppies the color-characters have been followed through another generation and several of the unit-characters involved have been recognized. Several pedigrees have shown the segregation of the characters into homozygous types. Many crosses have been made in order to determine the composition of each type which has appeared, and especially to compare each with the wild type of *Papaver rhœas,* from which the Shirley poppies are reputed to have sprung.

The greatest amount of space and attention have been given to studies of heredity in *Lychnis alba,* largely with reference to problems of sex-determination and sex-heredity. The rare occurrence of hermaphrodite mutants in this usually diœcious species has provided excellent material for the study of certain phases of the sex-problem. The great differences in the sex-ratios in different families and the usual excess of females over males present other problems of quite general interest and importance. Besides making observations on over 12,000 individuals of this species during the past season, more than 230 definite crosses have been made for the continuation of the work next year.

The comparative cultures of cross-fertilized and self-fertilized oenotheras have been continued and the tests of elementary species in *Lactuca canadensis, Erigeron ramosus,* and *Oenothera cruciata* have further demonstrated their permanence and distinctness.

A census of the cultures for the past season shows the following results:

	No. of pedigrees.	No. of individuals.		No. of pedigrees.	No. of individuals.
Chrysanthemum leucanthemum	1	10	Oenothera gigas	2	34
Erigeron ramosus	2	120	Oenothera lamarckiana	11	743
Helianthus annuus	29	2,039	Oenothera lata	1	47
Lactuca canadensis	5	447	Oenothera nanella	1	38
Lychnis alba	139	12,238	Oenothera rubrinervis	6	2,388
Lychnis chalcedonica	2	100	Oenothera scintillans	1	20
Lychnis haageana and varieties	6	301	Oenothera spp	2	32
Lychnis (Viscaria) splendens	1	55	Papaver rhœas	22	4,492
Nigella damascena	3	632	Verbascum blattaria	6	598
Oenothera cruciata	4	2,092	Verbena stricta	2	50
			Zea mays	41	4,000 (?)
			Total	287	30,476

Dr. J. Arthur Harris has had general oversight of the preceding cultures during Dr. Shull's absence. In addition to this work he has been making preliminary observations on species of Cucurbitaceæ, Passifloraceæ, Malvaceæ, and Solanaceæ, to determine their fitness for experimental work before serious and detailed studies are undertaken. He has also continued work along four other lines as follows:

Variation in Wild Plants.—During the year about the same progress was made in this work as reported in Year Book No. 7. Dr. Harris reports that the results of considerable of the work are nearly ready for publication.

Quantitative Investigations of Fertility and Fecundity in Plants.—The fitness of an organism to survive in the struggle for existence is of evolutionary significance only if it is also capable of leaving a sufficient number of descendants to give them an excess of weight in determining the characteristics of succeeding generations. This must be admitted, whether one holds that evolution is due to the accumulation of fluctuating variations or to mutations. Thus studies of fertility and fecundity are of cardinal importance in evolutionary investigations.

For some years past Dr. Harris has been accumulating extensive series of quantitative data on fertility in various wild and cultivated species. Some of the problems under consideration are:

The relationship between the degree of vegetative development and fertility and fecundity.
The correlation between the number of reproductive bodies formed and the number which develop to a stage in which they may function in propagation.
The correlation between somatic characters and fertility.
The relationship between symmetry in the fruit and fecundity.
Fertility and fecundity of homologous material under different environmental conditions.

Some of the results of these studies will be ready for publication shortly.

Investigations of Variation, Correlation, and Inheritance of Quantitative Characters in Garden Beans.—Dr. Harris's chief attention, since coming to the Station, has been given to quantitative investigation of variation, correlation, and inheritance of the minute differences commonly described as fluctuations, in several varieties of garden beans. The experiments are being carried out on an extensive scale in various habitats at the Station for Experimental Evolution, in eastern Kansas, the Missouri Botanical Garden, and southeastern Ohio. Some of the chief problems under consideration are:

The factors influencing the size of the bean seed.
A detailed investigation of the problem of pure-line inheritance, under various conditions and with several varieties.
The influence of the weight of the seed upon the characteristics of the plant developing from it.
The influence of environmental conditions upon the characteristics of individuals and their offspring.
The inheritance of fertility and fecundity.

This year the cultures were cut down to the lowest point possible to permit working up the large amount of material grown last year and to set time free for the larger experiments planned for 1911. About 15,000 individually recorded seeds were planted.

Studies in Vegetable Teratology.—In their bearing upon problems of mutation and fluctuating variation, series of teratological forms are of considerable interest. Experimental and statistical studies on proliferation of the fruit in *Passiflora* and *Capsicum,* and on seedling abnormalities in *Phaseolus* are being carried out by Dr. Harris. Extensive cultures of *Passiflora* and smaller series of *Capsicum* are being grown and their fruits dissected and classified. During the year about 40,000 bean seedlings were grown in the greenhouse to a sufficiently advanced stage of development to permit necessary determinations concerning abnormalities, and selected types have been transferred to the garden for inheritance studies.

CELL STUDIES IN HEREDITY.

These studies were continued by Miss Lutz, who reports as follows:

The work upon the somatic chromosomes of the oenotheras, begun in 1907 and reported upon in the two preceding Year Books, has been continued throughout the present season. As the problem requires a thorough knowledge of the vegetative characters and life-history of each individual plant, attention has been given exclusively to this study since the germination of the first seed and will be continued until the end of the flowering season. The winter months, as heretofore, will be devoted to the study of the chromosomes.

Of especial interest are the progeny derived from the artificial self-pollination of four offspring of *Oenothera lata* ♀ × *O. gigas* ♂, 1908. Of these, No. 3378, resembling *lata,* produced 12 offspring; No. 3368, resembling *gigas,* 52, and No. 3375, a plant with *gigas* number of chromosomes, but having some vegetative characters that resembled the female parent, 109. Five or six fixations of root-tips have been made, from each of these 173 plants for chromosome study; all have been carefully measured and described at regular intervals and many photographed in rosette and flowering stages.

Particular attention has been given to the F_1 offspring of *O. lamarckiana* ♀ × *O. gigas* ♂, derived from a single pair of pedigreed parents by means of guarded artificial cross-pollination. Each plant was also artificially self-fertilized and the offspring grown on either side of the hybrids in the garden for comparison with the latter (40 *lamarckiana,* 31 *gigas*). Observations were recorded in detail throughout the season, preservations made for bud, flower, and leaf measurements, and fixations for chromosome studies. Many also were photographed in various stages of development. Since *lamarckiana* is characterized by the presence of many basal branches (ordinarily 12 to 18, sometimes as many as 22) and *gigas* by their complete absence or presence in limited numbers (commonly not exceeding 3 in my cultures), this character became important in the study of inheritance among the progeny of this cross. Therefore 31 offspring were grown from seed of one artificially self-pollinated branched *gigas* having two basal branches and 31 from an unbranched individual.

Lata does not ordinarily mature pollen; but by opening several dozen buds daily for a week during the height of the flowering season enough pollen may occasionally be secured to artificially self-fertilize a flower. In this

manner seed was obtained during the summer of 1908 from 3 *latas* arising as mutants from pure-bred *lamarckiana;* these have produced respectively 73, 35, and 18 offspring during the season of 1909. (The same method was employed to secure fertilization of No. 3378 F_1 extracted *lata* derived from *O. lata* ♀ × *O. gigas* ♂, 1908, mentioned in the second paragraph of this report.) One individual from each of the three families has been artificially self-pollinated, and it is hoped that seed will be obtained for a second generation. Of equal interest is the cross between *O. lamarckiana* ♀ and *O. lata* ♂ (76 offspring) never before produced, so far as has been ascertained. The reciprocal cross (repeatedly grown at this station) was also included (45 offspring), but, owing to limitations of space and time for study, all of these two lots were discarded at the time of transplantation, except such mutants as were recognized among them.

All of the above-mentioned species, mutants, and hybrids have been the subject of individual daily study since germination and, as mentioned for the offspring of *O. lamarckiana* ♀ × *O. gigas* ♂, each has been carefully described at regular intervals throughout its life-history; leaves, buds, and flowers have been preserved for measurements, and (with the exception of a few recorded in the summary appended) five or six fixations of root-tips for chromosome study have been made from each of the above in early rosette stages.

The cross between *O. lata* ♀ and *O. gigas* ♂, studied in detail in 1908, was repeated to determine whether the offspring of a second cross would behave in general as did those of the previous season. 33 of the 71 plants under observation during early rosette stages were transplanted to the garden in May. No chromosome fixations were made.

The majority of the offspring of *O. lata* ♀ × *O. gigas* ♂ having shown themselves to be intermediate between the two parents, both in respect to external vegetative characters and number of chromosomes, I became interested in ascertaining whether two parents differing widely in number of chromosomes as do *lata* (15) and *gigas* (28–29 or 30) would not regularly produce intermediate offspring; also whether two parents having the same number of chromosomes, or differing in point of 1 (as *lata* 15, *lamarckiana* 14) might not produce, as a rule, only pure parental types among the offspring (exclusive of mutants), as had been demonstrated to be the case with *lata* ♀ × *lamarckiana* ♂. With this in view the following cultures were grown:

O. nanella ♀ × O. gigas ♂..... 90 offspring.
O. lamarckiana ♀ × O. gigas ♂.... 52 offspring.
O. nanella ♀ × O. lamarckiana ♂.. 134 offspring.

In addition to the above cultures 1 plant kept in sphagnum moss for two years was brought to maturity as a perfectly normal healthy *lamarckiana.*

Late in the summer young rosettes were found growing up from the roots of flowering F_1 offspring of *O. lata* ♀ × *O. gigas* ♂; one was removed from hybrid No. 3380, 2 from No. 3750, 4 from No. 3385, and 6 from No. 3372. These have been brought through the summer in excellent condition. An opportunity was here presented to observe the effect of external conditions upon the various cuttings taken from a single plant, with respect to bud-coloration, branching habits, size of adult plant, date of maturity, etc.

The following outline is added in conclusion to give a more concise idea of the investigations carried on during the season of 1909.

Culture.	Seeds sown.	No. of plants reared through early rosette stages.	No. of plants transferred to garden.	Date of transplantation.	No. of plants from which root-tip fixations were made for chromosome study.
O. lata (No. 3500), self-pollinated	Dec. 11, 1908	73	73	May 12, 1909	73
O. lata (No. 3527), self-pollinated	.....Do.....	35	35	.....Do.....	35
O. lata (No. 3571), self-pollinated	.....Do.....	18	18	.....Do.....	18
O. lamarckiana ♀ (No. 3814) × O. lata ♂ (No. 3500)	....Do..... / Feb. 1, 1909	76	8	May 13, 1909	8
O. lata ♀ (No 3500) × O. lamarckiana ♂ (No. 3814)	Dec. 12, 1909	45	3	May 12, 1909	31
O. lamarckiana ♀ (No. 3814), self-pollinated	Dec. 12, 1908 / Feb. 4, 1909	40	40	May 12, 13, 1909	5
O. gigas (No. 3672, basal branches), self-pollinated	Dec. 12, 1908	31	31	May 12, 1909	31
O. gigas (No. 3671), lacking basal branches, self-pollinated	.....Do.....	31	31	.....Do.....	31
O. lamarckiana ♀ (No. 3814) × O. gigas ♂ (No. 3672)	Dec. 14, 1908	52	52	.....Do.....	52
O. lata ♀ (No. 3500) × O. gigas ♂ (No. 3672)	.....Do.....	71	33	.....Do.....	1
Lata-like (No. 3378) F_1 offspring O. lata ♀ × O. gigas ♂, 1908, self-pollinated	Dec. 12, 1908	12	12	.....Do.....	12
Gigas-like (No. 3368) F_1 offspring O. lata ♀ × O. gigas ♂, 1908, self-pollinated	Dec. 14, 1908	52	52	.....Do.....	52
—— (No. 3375) F_1 offspring O. lata ♀ × O. gigas ♂, 1908, self-pollinated	.....Do.....	109	109	.....Do.....	109
Intermediate (No. 3379) F_1 offspring O. lata ♀ × O. gigas ♂, 1908, self-pollinated	Dec. 15, 1908	8	8	.....Do.....	8
Intermediate (No. 3750) F_1 offspring O. lata ♀ × O. gigas ♂, 1908, self-pollinated	.....Do.....	3	3.	.....Do.....	3
O. nanella ♀ (No. 3704) × O. lamarckiana ♂ (No. 3796)	Mar. 1, 1909	134	134	May 13, 1909	0
O. nanella ♀ (No. 3704) × O. gigas ♂ (No. 3671)	Mar. 2, 1909	90	90	.....Do.....	0
Lamarckiana (No. 1166) having remained in sphagnum moss as young rosette for 2 years	Feb. —, 1909	1	1	May 13, 1909	0
Cuttings from F_1 offspring O. lata ♀ × O. gigas ♂, 1908	.....	13	13	May 12, 1909	13
Biennials from 1908	.....	20	.....	.....	20
Total	.....	914	746	.....	502

HUMAN HEREDITY.

Although not strictly within the scope of experimental work, the necessity of applying the new knowledge of heredity to human affairs has been too evident to permit us to overlook it. For the last two years Mrs. Davenport and I have been collecting data on the inheritance of eye and hair characters. Last winter blanks for the record of family characters were prepared and distributed to the number of over 5,000 and over 250 of these have been returned. In many cases the greatest pains have evidently been taken to give full and accurate data. The reduction of these data will be begun at once. Only one character can be studied at a time and it will be at the best several years before all of the material can be utilized. Expectation is that it will eventually be possible, in the case of marriage of two individuals with the same characteristic or differing in respect to any characteristic, to state how the characteristic will be distributed among the children.

EQUIPMENT AND CONSTRUCTION.

During the spring the Department purchased Goose Island, one of the Norwalk Islands, belonging to the town of Westport and lying in Long Island Sound at a distance of 1.75 miles from the mainland, 0.5 mile from the nearest island of the group, Grassy Island. This island has the form of a crescent, the two arms of which at low tide partly inclose an admirable harbor whose shore is probably not less than 800 meters long. At high tide a grassy knoll is exposed, 200 meters long by about 30 meters wide at its widest part. This knoll is covered with a rich stony loam at least 1.3 meters deep, protected on all sides by a natural wall of stones, many of them nearly a meter in diameter. The northern part of the harbor has deep water, a bottom without rocks, and is well sheltered. The purchase will afford means of trying certain isolation experiments and of breeding some animals and plants under natural conditions without close confinement. In view of the distance of the island from the mainland and from the nearest island, and its position on the outer edge of the archipelago, it is well situated for the purpose. The principal difficulty to be anticipated is from trespassers. In the attempt to educate the public two large signs have been erected prohibiting trespassing. During the summer a list of the plants growing on the island was made by Dr. H. S. Conard and Messrs. H. H. York and Collins, and the animals were collected by students at the Biological Laboratory of the Brooklyn Institute. Among the animals the brown or Norway rat is very common and easily trapped. A small brown snake (*Storeria dekayi*), allied to the garter snakes, was found on the island. This snake can live for several hours on sea-water and probably swam from the mainland. No toads were found on the island, which contains no fresh water.

During the year the following pieces of work were finished by the constructor, Mr. Frank Allen: The cat-house, retaining-wall around shop, manufacture of additional cold-frames, stone steps on terrace from laboratory to residence, shed for wood-saw, concrete bridge on service road over ravine.

The Station launch *Eva* being too slow, small, and old for our purposes, it was sold and a 34-foot boat, the *Beagle,* with a 2-cylinder engine was purchased at a slightly higher price than that obtained from the sale of the old boat.

MAINTENANCE.

The source of our irrigation supply from Mr. Townsend Jones's spring was enlarged and improved, and the bed of the ravine was cobblestoned to prevent wear and conserve water. During the spring shrubbery was placed along the road to cut off automobile dust, electric connection with the buildings was made by an overhead wire (replacing underground cables), a burglar-alarm system was installed on the poultry plant, and an improved rack made in the shed for holding lumber.

GEOPHYSICAL LABORATORY.*

ARTHUR L. DAY, DIRECTOR.

The work which the Geophysical Laboratory has undertaken in determining the relations between the minerals which make up the accessible portion of the earth differs in two essential particulars from the somewhat tentative experiments which have preceded it: (1) only those properties have been seriously studied which could be quantitatively measured, and (2) only chemically pure minerals made or purified in the laboratory have been used. There are very definite reasons for approaching the great problem of rock formation in this way which, to the student of exact science, would seem to be obvious enough, but because these particular questions have rarely been brought into the laboratory for solution the methods of attack still have the appearance of novelty.

The situation is briefly this: Rock formation, like other physical and chemical phenomena, is the result of certain forces acting upon certain forms of matter. An exact knowledge of rock formation will accordingly depend upon the ability to establish definitely the characteristic properties of these particular forms of matter and to measure the forces which act upon it in each case. The fact that the individual rock-forming minerals do not occur in nature in great purity, and that the active forces are applied over a very great range of conditions and (in nature) over long periods of time, merely encumber the problem with technical difficulties of considerable magnitude; it does not, it must not be allowed to, confuse its analysis.

Undoubtedly it is true that considerations of this kind have had the effect of retarding and discouraging progress in this field when compared with some of the more accessible fields of research. This happens to have been its history, but it is equally true that no insuperable obstacle now stands in the way of the immediate and general application of modern quantitative methods to establish the relations of the minerals more than of the metals or of inorganic salts. Modern chemistry will provide minerals of adequate purity; the conditions, although many and varied, have now been very generally found to be definable and accurately reproducible, and the long periods of time occupied in the growth of natural rocks were perhaps a consequence of the immense mass of participating material and its aggregate energy content rather than a necessary factor in the reactions which took place. Few of the mineral relations so far studied require prohibitive intervals of time for their development.

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* Situated in Washington, D. C. Grant No. 539. $45,000 for geophysical research. (For previous reports on geophysical work see Year Books Nos. 3, 4, 5, 6, and 7.)

The usual limitations upon the pioneer settler in new territory of course obtain here. He may not at once begin as he would, but must begin as he can. That is, the questions which must be chosen for initial solution are not always those which the experience of the geologist has pointed out as most important and far-reaching in their geological application, but rather those which can be reached by the methods and apparatus already available, or others suggested by experience. Once a beginning has been made, useful experience accumulates rapidly, and, indeed, in a new field this is perhaps the most valuable product for a time.

It is obvious that in proportion as the new conditions approach familiar ground there is more variety in the available methods, greater certainty in their application, and greater immediate progress. But a more far-sighted survey of the field plainly reveals the fact that ultimate progress will depend largely upon the extension of the facilities for reproducing the extreme conditions under which rock formation proceeded in the great laboratory of nature.

For this reason it has not been the policy of this Laboratory to multiply indiscriminately such observations and measurements as have already proved practicable and effective, but rather to put forth a consistent effort to extend their scope in directions which have hitherto been regarded as more or less inaccessible. This plan of procedure has also an immediate practical advantage in that new methods once established become available to others who may be interested to continue such research.

It is a matter of common belief which has had considerable foundation in fact that the reason why the search for more exact information about the formation of the earth and its mineral resources was not begun long ago was because a special and uncommonly powerful plant was necessary for the competent solution of these problems. This is to a certain extent true, but the situation is by no means as serious as in astronomy, for example, where a particular relation will only yield to the analytical power of a telescope of a certain size and smaller instruments are left helpless. With greater experience in the laboratory study of the minerals, it is becoming more and more evident that the reactions go forward as regularly where small quantities of material are under observation as with larger ones, and that the measurements undertaken upon the smaller charges are often more accurate and conclusive. The study of the relations of many of the rock-forming minerals is therefore already within easy reach of a comparatively modest laboratory equipment.

As soon as we begin to realize that a number of the important problems of rock formation are really within the facilities regularly offered to students in many educational institutions, an immense impetus will be given to the development of the subject, as well as to the aggregate output of trustworthy data

upon petrogenesis. Several papers by Dr. Walter P. White (of which brief reviews are appended) are devoted particularly to a detailed exposition of the character of mineral melting-points and specific heats which may be readily observed and the necessary apparatus prepared in almost any good physical laboratory without extravagant expenditure. We count this one of the most important steps in the progress of the present undertaking,

The work of the past year has been especially successful in three principal directions:

(1) The specific heat of several pure mineral types has been successfully measured up to 1500° C. with an accuracy comparable with that obtained in similar measurements at ordinary temperatures and under the most favorable conditions.

(2) A two-component mineral system has been successfully worked out in which temperatures as high as 2100° C. (more than 300° above the platinum melting-point) were necessary.

(3) Apparatus has been developed for exposing minerals to measured pressures of 17,000 atmospheres and temperatures as high as 700° at the same time. The methods of pressure measurement in these preliminary tests are somewhat crude and are capable of considerable refinement, but the development of apparatus in which so much energy could be concentrated in a small space, maintained under control and measured, offers greater hope of success in approximating to the more inaccessible conditions of rock formation in nature than was at first anticipated. These measurements have been prepared for publication in current numbers of the scientific journals and will be reviewed briefly under the published work of the year.

GEOLOGIC THERMOMETRY.

The question whether more exact and extensive knowledge of the characteristics of the minerals, both alone and in combination, will enable the temperature of formation of individual portions of the earth to be established with certainty, is one of immense geologic importance. The accumulation of data of the kind and quality required for this purpose, upon a great number of minerals, is necessarily slow, but the experience of the Laboratory so far appears to indicate conclusively that it is only a matter of time when positive conclusions of this character can be made.

The reasons for this statement can be given briefly. One in particular has long been recognized in geologic literature and is already familiar. The order of segregation, or differentiation as it is frequently called, of individual minerals and groups of minerals from a given magma (solution) can be established in the laboratory and identified in natural rocks, first for simple cases and afterward for more complicated ones. This may not be done just in the way in which it has been attempted heretofore, by inference from the size of the grains, the character of the inclusions, etc., although this is all

valuable circumstantial evidence; but rather from known (several have now been worked out) temperature relations existing between crystals of the same composition but of different crystal form.

One or two simple cases taken from the recent work of the Laboratory will suffice to illustrate the point. The mineral $CaO.SiO_2$ melts readily at a temperature a little over 1500° C. If it is cooled again and recrystallizes at that temperature, a crystalline mineral known as pseudo-wollastonite results. If it does not recrystalize promptly (and most minerals and mineral mixtures do not), but cools quietly below 1200° and crystallizes there, wollastonite, a familiar natural mineral, results. Chemically the two minerals are identical, crystallographically they are different. The presence of original crystals of wollastonite in a rock is therefore proof positive that its formation occurred below 1200°.

Some mineral compounds possess more than two crystal forms in the solid state and thus receive further distinguishing marks long after the segregation from the original magma is complete. Calcium orthosilicate, for example, possesses three crystal forms,* magnesium metasilicate five,† pure silica (quartz) six,‡ etc., and each is formed in a definite temperature region which is measurable. Some, upon cooling, pass readily through several of these states in succession; others show much inertia in passing from one form to another (inversion) and lag behind the temperature for a time; some of the transitory states leave their permanent imprint upon the final form, while others do not. Quartz, for example, which is the most conspicuous and widely distributed of the minerals mentioned, offers in itself quite a scale of temperatures of direct geologic application. Although the interrelation of all the six forms (α and β quartz, α and β tridymite, α and β cristoballite) has not yet been completely worked out, at least four valuable geologic temperatures have already been determined: (1) The transition (inversion) from α to β tridymite, occurring at 130° (reversible); (2) from α to β cristoballite at 175° (reversible); (3) from α to β quartz at 575° (reversible); (4) from β-quartz to β-cristoballite at 800° (reversible).

In the same way the relation of the bands in minerals which show zonal structure, like the lime-soda feldspars, have a definite temperature significance to which attention has already been directed§ but upon which little detailed work has yet been done.

With the exception of quartz, these relations have merely been established and the temperatures fixed as a part of the systematic study of the conditions

* The lime-silica series of minerals. Am. Journ. Sci. (4), 22, 294, 1906.

† Minerals of the composition $MgSiO_3$; A case of tetramorphism. Am. Journ. Sci. (4), vol. 22, 437, 1906; Diopside and its relations to calcium and magnesium metasilicates. Am. Journ. Sci. (4), vol. 27, 16, 1909.

‡ The binary systems of alumina with silica, lime, and magnesia. Am. Journ. Sci. (4), vol. 28, 322, 1909.

§ The isomorphism and thermal properties of the feldspars. Publication No. 31, Carnegie Institution of Washington, p. 70.

of equilibrium of the mineral types thus far chosen for investigation, leaving their application to natural rocks to the geologist whenever sufficient data shall have been gathered to serve the purpose effectively.* In the case of quartz, direct application was made of these data to a considerable collection of typical specimens of natural quartz from known localities with most interesting results, illustrative of the possibilities of more extensive studies of this kind, using all the temperature data available from the common minerals. A brief review of this paper follows (Quartz as a geologic thermometer).† The application to natural rocks will become even more conclusive and productive when a greater body of such data has been gathered and when the rôle of water in rock formation has become more thoroughly understood, but there would appear to be no longer any doubt of the ultimate practicability of establishing such formation temperatures with great certainty.

TEMPERATURE STANDARDS.

The research on the absolute measurement of high temperatures with the gas-thermometer, of which the preliminary results were published a year ago,‡ has been successfully continued throughout the year and is expected to be completed about January 1, 1910. The most important features which have developed since the publication referred to are perhaps these:

(1) An alloy of rhodium and platinum has been substituted for platin-iridium as the bulb material, which reduces the contamination of thermo-elements necessarily exposed in the furnace with the bulb to about one-fifth of its former magnitude.

(2) New determinations have been made of the expansion coefficient of the new bulb material (80 parts platinum, 20 parts rhodium).

(3) A new source of error has been discovered in the radiation of heat from the ends of the bulb toward the cold ends of the furnace which operates to raise the published temperatures of a year ago about 1.5° C. The error is readily eliminated.

(4) Observations with the gas-thermometer have now been successfully continued beyond the limit of a year ago (1100°) to the melting-point of nickel (1452°) with the same order of accuracy (copper melting-point, 1082 ± 1°; nickel melting-point, 1452 ± 2°).

(5) Absolute determinations of the temperature of melting copper with the new bulb (platin-rhodium) agree with those made with the old bulb (platin-iridium) within 0.5°, although the form of the bulb, the furnace coil,

* G. F. Becker, Harald Johannsen, and others have already made considerable use of data of this kind in the discussion of important geologic problems.

† Also the binary systems of alumina with silica, lime, and magnesia. Am. Journ. Sci. (4), vol. 28, 322, 1909.

‡ Some new measurements with the gas-thermometer. Am. Journ. Sci. (4), vol. 26, 405, 1908.

and consequent temperature distribution within and many of the conditions of measurement were purposely changed in the new determination. This leaves little doubt of the absolute character of the new temperature scale.

THE PLANT.

Except for the addition of a 500-ton press and a hydraulic accumulator, together with suitable feed-pumps and gages, no considerable change has been made in the permanent equipment of the Laboratory. Dr. Albert Ludwig, of Dusemond, Germany, who spent sixteen months at the Laboratory as a research associate, and to whose experience we are chiefly indebted for the success of the pressure plant and of the work so far undertaken with it, has now finished his work and returned to Germany.

PUBLISHED WORK OF THE YEAR.

Brief reviews of the papers published by members of the Laboratory staff during the year follow:

(1) Ein Projections-Transporteur. V. Goldschmidt and Fred. Eugene Wright. Zeitschr. f. Kryst., 45, 569. 1908.

A brief description of an apparatus for laying out in gnomonic and stereographic projection the position angles $\phi\ \rho$ and $\nu\ \rho$ obtained in measuring crystals with the two-circle goniometer.

(2) Das Doppel-Schrauben-Mikrometer-Okular und seine Anwendung zur Messung des Winkels der optischen Achsen von Krystalldurchschnitten unter dem Mikroskop. Fred. Eugene Wright. Tschermak Min. u. Pet. Mitth., 27, 293. 1908.

In thin sections minerals are identified and determined according to the various optical properties whereby the importance of a given optical property is to a certain extent dependent upon the degree of its independence of the plane in which the slide is cut. In anisotropic minerals, the angle of the optic axis, and therefore the optical character, is an extremely important and useful diagnostic property, but until recently its measurement could only be carried out upon a very limited number of sections of especially favorable minerals and was therefore not generally available. Professor Becke has recently devised a drawing-table by the use of which the angle of the optic axes can be determined upon any thin section in which at least one optic axis appears in the field, which has considerably increased the usefulness of this property. This paper describes a new method by which similar measurements can be made with a new double-screw micrometer ocular. A comparison of this method with the Becke drawing-table method shows that the two are in general equally applicable and that the results in sections where both axes appear in the field are more accurate than in other sections. The error in this case amounts to only $\pm 1°$, while if only one optical axis is in the field the probable error in the most favorable cases is 2 to 3° for the micrometer ocular and 4 to 5° for the Becke drawing-table. The time required for the measurement is about one-half of that necessary with the drawing-table and the personal equation which enters in the case of the latter

method does not enter in the former. Meanwhile, both methods ought to be considered as approximate, giving good results only under the most favorable conditions, where the axial bars are sharply developed and the influence of double refraction can be neglected.

(3) Artificial daylight for use with the microscope. Fred. Eugene Wright. Am. Journ. Sci. (4), vol. 27, 98. 1909.

An account of the successful employment of acetylene light, a large condensing-lens, and a pale-blue glass ray-filter in place of daylight, with the petrographic microscope.

(4) A new goniometer lamp. Fred. Eugene Wright. Am. Journ. Sci. (4), vol. 27, 194. 1909.

A convenient arrangement for the use of an acetylene flame in goniometric measurements upon minute crystal faces. It has proved to be more generally serviceable than the electric arc or the Nernst glower, is inexpensive, and can be assembled in a few hours from the resources of any shop.

(5) A containing device for salts used as sources of monochromatic light. Fred. Eugene Wright. Am. Journ. Sci. (4), vol. 27, 194. 1909.

The device consists of a small platinum crucible (about 2 cc.), which can be attached to a Bunsen burner in such a position that the flame plays upon one side of the crucible and keeps the salt melted. From the interior of the crucible a bundle of small platinum wires extends out into the flame and serves as a wick. The flow of material is continuous and the flame remains constant for long periods of time without attention.

(6) Ueber die Anwendbarkeit des Nernstchen Wärmetheorems auf einige heterogene Gleichgewichte. John Johnston. Zeitchr. f. Phys. Chem., 65, 737. 1909.

The application of strict thermodynamic principles to the calculation from existing experimental data of the free energy changes attending the formation of certain carbonates, hydroxides, and oxides leads to results which exhibit satisfactory concordance between calculated and experimental values; the Nernst approximation formula, however, applied to the calculation of the same heterogeneous equilibria, does not in general give correct results, and hence it is to be classed as an empirical rule along with the similar rules of Le Chatelier and de Forcrand.

(7) Quartz as a geologic thermometer. Fred. Eugene Wright and Esper S. Larsen. Am. Journ. Sci. (4), vol. 27, 421. 1909.

In this paper attention is directed to a geologic thermometer-scale the points for which are to be sought in the stability ranges of the different phases of rock-making minerals (their melting and inversion temperatures), and also in the melting temperatures of certain mineral aggregates (eutectics). Quartz is well adapted to furnish at least one and possibly two points for the geologic thermometer scale, since on heating at 575° it suffers an enantiotropic change to a second phase, called β-quartz by Mügge, while above 800° it is no longer stable at ordinary pressures, but passes into tridymite. Following the example of Le Chatelier and Mallard, the point of inversion of α and β quartz was redetermined by observing the abrupt change in the birefringence, circular polarization, and expansion coefficient at that temperature. The most accurate optical determinations place this inversion

temperature at $575 \pm 2°$. Proofs that these represent an energy change were obtained by the perceptible variation in heat capacity in this region by the Frankenheim method of heating and cooling curves, and also by direct determination of the specific and latent heats in this region.

Crystallographic proof of the change has been studied in detail by O. Mügge, who finds the high temperature phase, β-quartz, to be in all probability hexagonal and trapezohedral-hemihedral, while the low-temperature α-quartz is hexagonal and trapezohedral-tetartohedral. This particular relation between the two phases entails certain consequences which can be used as criteria to distinguish quartz which has been heated above 575° from quartz which has never reached that temperature.

These criteria were in large part indicated by O. Mügge and have been applied here to a number of natural quartzes occurring in different kinds of rocks, the net result of the investigation being that vein and geode quartzes and certain large pegmatite quartz-masses and pegmatite veins were formed below 575°, while graphic and granite pegmatites and granites and porphyry quartzes were in all probability formed above 575°. With the quartzes thus examined were associated other minerals, the order of precipitation of which relative to that of the quartz could be determined in certain instances, and thus temperature limits for the formation of these in turn ascertained.

(8) The relation between the refractive index and the density of some crystallized silicates and their glasses. Esper S. Larsen. Am. Journ. Sci. (4), vol. 28, 263. 1909.

An experimental study of the refractive indices and densities of silicate glasses and of artificial minerals to test the formulæ of Gladstone and Dale and of Lorentz and Lorenz. Neither the refractive indices nor the specific volumes of the glasses are strictly additive functions, but there may be an increase or a decrease of volume and a corresponding decrease or increase of the refractive index. The specific refractivity computed from either formula is sensibly additive for the glasses and nearly so for the isomorphous series of soda-lime feldspars, but when crystals are compared with glasses of the same composition, or with other crystals, the values of the specific refractivity, computed from either formula, may differ by as much as 11 per cent. They are usually higher for the glasses. One formula appears to hold as well as the other, but the formula of Gladstone and Dale has the advantage of simplicity.

(9) The binary systems of alumina with silica, lime, and magnesia. E. S. Shepherd and G. A. Rankin. With optical study by Fred. Eugene Wright and E. S. Larsen. Am. Journ. Sci. (4), vol. 28, 293. 1909.

This paper contains a large body of experimental data and descriptions of a number of methods which have been developed in the course of the study of the three 2-component systems mentioned, which do not admit of brief review. The fact that it has proved practicable to make reasonably accurate determinations of mineral relations at a temperature as high as 2100° C. is by no means the least important result of the experimental work. The most important relations found to exist between the above components are these:

(1) There is but one compound (Al_2SiO_5) of alumina and silica stable in contact with the melt. This is the mineral sillimanite. The two minerals

andalusite and cyanite pass slowly into sillimanite on being heated above 1300° C.

(2) There are four definite compounds of lime with alumina, namely, $3CaO.Al_2O_3$; $5CaO.3Al_2O_3$, melting-point 1387° C.; $CaO.Al_2O_3$, melting-point 1587° C.; $3CaO.5Al_2O_3$.

(3) $3CaO.Al_2O_3$ and $3CaO.5Al_2O_3$ have no true melting-point, but the former will be completely melted at about 1550° C. and the latter at about 1725° C.

(4) Two of these compounds, $5CaO.3Al_2O_3$ and $3CaO.5Al_2O_3$, have an unstable form each, while $3CaO.Al_2O_3$, and probably $3CaO.5Al_2O_3$, are unstable at the melting-point, *i. e.*, do not produce a maximum on the liquidus.

(5) There is one compound, $MgO.Al_2O_3$, between magnesia and alumina.

(6) There is reason to believe that the system MgO.CaO is a eutectic series with no compound, and little, if any, solid solution. The temperature range is too high for satisfactory investigation.

Having established the nature of the binary systems, experimental study of the ternary system $CaO–Al_2O_3–SiO_2$ is now under way.

Complete optical data are given for all the preparations studied, and in conclusion a brief discussion of the geologic significance of the various kinds of measurements, chemical, thermal, and optical, which can be competently undertaken in the laboratory.

(10) Specific heats of silicates and platinum. Walter P. White. Am. Journ. Sci. (4), vol. 28, 334. 1909.

For determining the specific heats of silicates up to 1500° C., the method of mixtures in which the heated substance is dropped from a furnace into a calorimeter at room temperature was selected as the most accurate. The chief source of error is in the lack of uniformity of furnace temperature. This has been diminished in some cases by special forms of furnace. The error introduced in the process of transferring from the furnace to the calorimeter is negligible. An electrical method of dropping greatly reduces the time required, and determinations made with the containing crucible alone eliminate what heat loss there is.

All temperatures, including that of the calorimeter, were read by thermoelements. By this means rapidity and simplicity of manipulation were secured.

The calorimeter was completely inclosed by its water-jacket. An unusual temperature rise (sometimes 23°) was successfully employed to increase accuracy. Some simple ways of treating specific heats mathematically are given.

A consideration of the various sources of error indicates for the mean specific heats a final accuracy of better than 0.5 per cent at most temperatures. This conclusion has been strengthened by the results obtained with a special furnace. The true specific heats, derived from these, are less accurate. Silicate specific heats show, after a considerable increase with temperature up to 700°, a tendency to diminish at higher temperatures.

(11) On the dependence of valence upon volume in certain trivalent elements. A. Ludwig. Journ. Am. Chem. Soc., 31, 1130. 1909.

A study of the effect of pressures from 6,000 to 17,000 atmospheres upon bismuth, antimony, and aluminium in the presence of water vapor near their

melting temperatures. In the cases of bismuth and antimony the formation of the monoxide was established by separation and analysis. The physical behavior of aluminium indicated the formation of the monoxide of it also, but it was not found possible to separate it from the metal by methods then available.

The essential experimental feature of the problem was the development of a pressure-bomb in which temperatures as high as 700° could be maintained for short intervals at these immense pressures. Several such bombs were finally made upon the successful design which held perfectly tight under these conditions and which may prove of great value in the study of those mineral formations in which pressure is supposed to have played the principal rôle.

(12) Melting-point determination. Walter P. White. Am. Journ. Sci. (4), vol. 28, 453. 1909.

Actual melting- and freezing-point curves are nearly always oblique—that is, they show, not the constant temperature called for by elementary theory, but instead, an interval within which the temperature continuously rises or falls. The prime cause of obliquity in melting curves is the obliquity of the melting itself, due to impurity. The true melting-point is the high end of the oblique melting interval. The melting hysteresis of some very viscous substances (mostly compounds of boron and silicon) is also an occasional cause of obliquity.

A number of causes of obliquity lie in the experimental determination of the behavior of the melting and freezing substance. The determination of a melting-curve necessarily involves two factors—temperature rise and heat supply; the latter depends on the temperature difference of furnace and melting charge; if this varies, the curve is distorted in a way striking but easy to correct. The most conspicuous example is where the furnace temperature is allowed to rise or fall continuously, while the substance, melting or freezing, remains nearly stationary. The freezing-point, coming at the beginning (in time) of the interval, where temperature distribution in the charge is relatively uniform, is easier to observe than the melting-point, but is inadmissible in substances where undercooling is marked.

The melting-point, coming at the end (in time) of the interval, is liable, where stirring is not practiced, to obliquities resulting from uneven temperature distribution: (1) due to the inevitable temperature difference between inside and outside of the charge, troublesome with large charges, negligible with small; (2) due to various irregularities in heat flow, less with narrow charges and small thermo-elements, hardly ever over a degree or two; (3) due to conduction of heat down the thermo-element, also less with narrow charges and small thermo-elements, for which it is usually negligible, but possibly amounting to several degrees with inclosed elements.

Electrical conductivity in the melt produces an error in the reading of bare thermo-elements, thus far negligible in small charges of salts. Contaminated elements, besides reading false, read so as to increase obliquity. Differentiation and diathermancy of the charge probably increase obliquity. Meltings have been made above 800° agreeing with each other to 0.05°. In most cases an experimental obliquity remains of from 0.5° to 1.5° whose cause is still to be definitely determined.

(13) Melting-point methods at high temperatures. Walter P. White. Am. Journ. Sci. (4), vol. 28, 474. 1909.

Platinum resistance-furnaces of simple construction provide complete control of the temperature for melting-point work up to 1,600° C. Where uniformity of temperature throughout the working-chamber is important, special modifications are necessary. Small charges (2.5 grams) give very sharp melting-points, are economical of material, and permit of convenient manipulation.

A number of advantages result from the use of a second thermo-element, which is made to give directly the furnace temperature about the charge. The measurement and regulation of the heat supply from the furnace is a factor of great importance in accurate melting-point determination. Methods of treating and insulating thermo-elements and of avoiding the effects of contamination have been developed, suited to various conditions and kinds of work.

The melting-points of very viscous substances, showing hysteresis, can be determined easily and effectively by very slow heating and occasional examination outside the furnace. The approximate determination of latent heats of fusion directly from melting-curves is possible by measurement of the furnace temperature, but is encumbered by several hitherto undetermined sources of error. The attainment of an accuracy greater than 10 per cent (about 10 calories in many silicates) accordingly requires special apparatus and procedure. The smaller latent heats of inversion can often be determined to 1 or 2 calories, with no other apparatus than the two thermo-elements. For determining faint or sluggish thermal effects rapid rates of heating and the utmost precision in furnace regulation and temperature measurement are needed. The accurate location of eutectics by thermal means requires the detection of small residues of the component in excess. This can be accomplished by a special method involving the use of a neutral body.

DEPARTMENT OF HISTORICAL RESEARCH.*

J. Franklin Jameson, Director.

The following report, the fourth annual report of the present Director, covers the period from November 1, 1908, to October 31, 1909. The regular staff of the Department has remained unchanged throughout the year, the historical (as distinguished from clerical) workers being the Director, Mr. Leland, Miss Davenport, and Dr. Burnett. In addition, it has had through most of the year, December to September, the aid of Dr. James A. Robertson, and through about half of it, January to June, that of Mr. David W. Parker.

From November to October the Department occupied the same rooms in the Bond Building as hitherto—three rooms greatly crowded and much exposed to noise and dust. From the latter part of June to the middle of September its office work was carried on in excellent quarters in the beautiful library building of Bowdoin College, at Brunswick, Maine, where the librarian and his staff showed us every courtesy and gave us unusual privileges. Most grateful thanks are due to the president and faculty of the college for placing such rooms and such opportunities at our disposal. The practice of removal in summer costs the Department something in money and in remoteness from the Library of Congress, but the cost is, in the case of at least a part of the staff, compensated by the superior efficiency with which one can work in such a climate as that of Maine.

The general plans of the Department continue to be those which were set forth in my first annual report. Its main function must be to do, for as many first-rate investigators in American history as possible, what they can not easily do for themselves and what is not likely to be done for them by other agencies already existing, either by providing in print materials hitherto difficult of access or use, or by shortening and improving the pathway between the workers and the materials for their work.

The principles on which an endowed department of historical research should operate are clear; their application presents some difficult problems. It is necessary, in order to avoid duplication or other unprofitable action, to form a judgment as to what existing agencies are likely to do. It is not hard to acquire the necessary information on which to base such a judgment, especially as many of them have local fields of work, or fields otherwise well defined. It is also necessary to form a judgment as to what lines of investigation in American history are, at the same time, best worth following and

* Address, Bond Building, Washington, D. C. Grant No. 540. $20,500 for investigations and maintenance. (For previous reports see Year Books Nos. 3, 4, 5, 6, and 7.)

most likely to be followed by a considerable number of the better sort of investigators within the next twenty-five years. Each generation views the past in its own way, asks questions concerning it which preceding generations have not asked, and requires that history be written anew in such a manner as to answer them. Even if it were possible to divine with security what are the most profitable lines of investigation to follow with a view to meeting the needs of the next generation, it would still remain difficult to be sure what collections of material, what reports or inventories, are most likely to be extensively used by the class of investigators one would most wish to serve, the maturest and most talented members of the historical profession.

The answer, indeed, is clouded by doubts arising from the present status of that class. One who has watched the progress of historical investigation in the United States during the past ten years will doubt whether during that period, in spite of the marked improvement in local work and the great increase of respectable doctoral dissertations, the amount of work of the highest grade has increased at all. In a régime of rising prices and salaries thereby diminishing, and in a land of such rapidly increasing wealth that the general reader has become a bonanza and that any history of the United States can find an enormous sale if it is only made sufficiently voluminous and expensive, we are not to expect the best of the academics universally to prefer the austere prosecution of the unprofitable to the golden rewards of publishers' enterprises.

The conditions are doubtless in large part temporary; for instance, we can rely upon increased appreciation of the teacher's function to shame or persuade American mankind into the increase of his pay, and as the culture of the American rich becomes less superficial we can count upon a large recruitment of the workers in history from that class, from which has come in every age and country a large part of those devoted to that expensive pursuit. The future of historical investigation in America is not dark; but its immediate course is perplexing. We must do our best to estimate the direction and volume of its flow, but can not be surprised if our calculations are not always verified by the result, our publications not always so immediately useful as we had hoped.

Those publications, as has been explained in previous reports, fall naturally into two classes, the one that of reports, aids, and guides, the other that of textual publications of documents. Under these two heads, and a third relating to the miscellaneous activities of the Department, the work of the past year and the plans for 1910 will be successively considered in this report.

WORK OF THE PAST YEAR.

REPORTS, AIDS, AND GUIDES.

At the date of the last report the Institution was about to issue the "Guide to the manuscript materials for the history of the United States to 1783, in the British Museum, in minor London archives, and in the libraries of Oxford and Cambridge," by Prof. Charles M. Andrews and Miss Frances G. Davenport. This book, a substantial volume of 513 pages, was brought out in February, 1909. Its character was sufficiently described a year ago. It is pleasant to be able to report that its plan and execution have met with favorable criticism; an appreciation especially valued was that contributed by Prof. Herbert L. Osgood, of Columbia University, to the July number of the American Historical Review (XIV, 829).

Probably the next most important of our enterprises in foreign archives is the endeavor which Mr. Leland, of our staff, has been making to compile a guide to the materials for the history of the United States and Canada, which are to be found in the various archives of Paris. Shortly after the date of the last report Mr. Leland returned from his first expedition, after a stay of seventeen months in that city. It was seen that a second expedition of several months would be requisite.

The reasons, briefly stated, were that the French archive-materials are in several different depositories, as is the case with those of Washington, not concentrated, as the British archive-materials are, in one general Public Record Office; secondly, that, because of the large amount of data which, for one portion of the field, the Canadian Archive Branch has already published, a summary description would mark too little of an advance upon what we already possess for that portion, and a fuller description of all portions could be constructed with relatively little additional labor; thirdly, that the relations of France to the British colonies in America and to the United States in their earlier years were in general not such as leave in archives a deposit of long series or large masses of uniform matter, capable of adequate description in few words, but, on the contrary, were such that the papers referring to them, while numerous, are mostly embedded in series of papers not mainly American, so that the American papers have almost to be listed.

Accordingly, Mr. Leland, after a winter spent partly in the office-work of the Carnegie Institution, but mostly in that of the American Historical Association, of which he was elected secretary at Christmas-time, proceeded again to Paris in the latter part of June. He has spent July and the three ensuing months chiefly among the manuscripts of the Bibliothèque Nationale and in the Archives des Affaires Étrangères. In the former he at first devoted himself especially to the extensive collections of Pierre Margry; in the latter the chief objects of his attention have been the series called "Correspondance Politique, États-Unis," and "Correspondance Politique, Es-

pagne," the first being wholly in his field, the second containing large amounts of material relating to it. He has also completed, at the Ministry of War, his examination of the principal series in the Archives Historiques, Anciennes. Assistants employed by him have meanwhile searched at the Archives Nationales the papers of the legislative committees and the police in the Revolutionary and Napoleonic period and have examined for him parts of the manuscript material in the Bibliothèque Nationale.

Mr. Leland is making, as was explained a year ago, an inventory marked by a somewhat higher degree of explicitness than most of these manuals in our series. That his laborious task is not yet completed is due partly to the natural expansiveness of such pieces of work, partly to the proposed removal and transfer of the archives of the Ministry of the Colonies, and partly to the fact that the Ministry of Foreign Affairs has extended from 1830 to 1848 the date down to which the examination of its archives is permitted, an action very gratifying in itself, but one which makes a large addition to the amount of material to be inspected. As Mr. Leland must on other accounts return to America in November, 1909, another expedition, to finish the book, must be made in 1910.

Professor Bolton has found that the pressure of his work at the University of Texas during the past academic year and that which has resulted from his call to Leland Stanford University have made it impossible for him to complete all the manuscript of his report on the Mexican archives examined during the period of the last report. It is understood, however, to be nearly finished. He has completed the searches themselves by examining the archives of three present-day or former provincial capitals in northern Mexico—Monterey, Saltillo, and Monclova—in which large materials for United States history were found.

Prof. Carl R. Fish, of the University of Wisconsin, spent the year, from October to June, in Rome making a guide to the materials for American history in the archives of that city. The field was one of exceptional interest, including as it did the records and papers arising from the general relations of the Catholic Church to America, those of missionary organization and enterprise, those arising from the diplomatic position and activities of the Curia, and the secular archives and libraries of the Kingdom of Italy; and it was a field hitherto but very little worked for American purposes.

Mr. Fish seems to have received every needed facility for his work. There is no narrowness in Rome in such matters, and since the opening of the Vatican archives by the late Pope in 1880 freedom of access has been the rule. An exception was apprehended in the case of the archives of the Congregation of the Propaganda. This collection, of the greatest importance for American history, was open to scholars for some ten years in the period directly after the opening of the archives of the Vatican, but subsequently, for administrative reasons, access was almost entirely cut off. Mr. Fish,

however, has been enabled to make a full report upon its contents. His data have been derived principally from this collection, from the registers of bulls and briefs at the Vatican, and from the correspondence of the papal secretaries of state in the latter archive, particularly the dispatches of the nuncios in Spain, France, Flanders, and other countries. The Vatican and other ecclesiastical libraries of the city, and its many public libraries, were also searched.

Brief investigations were made in a few other Italian capitals besides Rome. Those inquiries which Mr. Fish on his way to Rome prosecuted in the archives of Turin and Florence, former capitals of the kingdoms of Sardinia and Italy, were mentioned a year ago. From Rome he made a brief expedition to Naples, where the state archive contains not only the archives of the Kingdom of the Two Sicilies, but those of the Farnese family; one section of the latter is in effect a supplement to the archives of the papal secretary of state in Rome. After leaving Rome he also examined the archives of the Republic of France.

Upon all this research Professor Fish has submitted a report not yet wholly revised in all respects but complete in substance, which will amount to a volume of considerable size. Its method has been based upon the facts in the case. The total bulk of the American material in the Roman archives is naturally much less than in those of England or Spain, and such as exists is seldom found in collections or series special to the subject, but is dispersed at large. To give merely general descriptions would be of little use; to examine exhaustively every volume where an American document might lurk was impossible to one having but a year's time. The method employed, in the Vatican archives and elsewhere, was a compromise between the two: to study thoroughly a few volumes of every set which might be supposed to contain anything relating to America, and to enter in the report, in addition to the general description of the whole, the exact findings in these volumes, as well negative as positive.

The data listed are in the main confined to papers relating to the area of the present United States and Canada; but in view of the close ecclesiastical relations which formerly bound the once-Spanish portions of the United States to Cuba and northern Mexico, the geographical restriction has been wisely relaxed in many cases. Impossible as it is for any one man to explore completely the vast contents of the Roman archives, and largely as the detailed portions of Mr. Fish's report must therefore rest on a selection of specimen volumes, nothing can be more certain than that it will powerfully stimulate American research in this almost virgin field, effectively aid those who attack these and other volumes, and do much to promote a fuller knowledge of the history of ecclesiastical, Spanish, and French America.

The archive-search which Prof. Marion D. Learned, of the University of Pennsylvania, has been conducting for the Department in Germany is of a

different sort from most of those hitherto undertaken. In most of the previous cases it has been expedient, in spite of the attractive possibilities lying in provincial and local archives, to leave them at one side for the present and to confine attention, in the first instance, to central or national archives, more abounding in material and more certain to be resorted to by students; and in each such case the main mass of the American material is due to the relation of the government in question with the government of the United States or its predecessors.

In the German case the main object of historical attention is different. The relations of the Prussian and other German governments to that of the United States have some importance, and their diplomatic archives and those which relate to the Hessian troops and other matters of a political character should be subjected to careful examination. But the main historical relation of Germany to the United States is not that of a political state or states, but that of the German nation as the source of a large fraction, perhaps one-fifth, of the American population; and the subject best worth our investigating in the archives is that of the German emigration to America in the seventeenth, eighteenth, and nineteenth centuries. To furnish a guide to researches in this line was made distinctly the object of Professor Learned's mission. To pursue it required researches in provincial and local quite as much as in central archives.

German archive-administration is, however, to such a degree centralized that the higher officials can do much to promote the success of inquirers in local archives, and it would be difficult to exaggerate the expression of our indebtedness to Geheimregierungsrath Dr. Reinhold Koser, director of the Prussian archives, and to His Excellency Geheimrath Professor K. Th. von Heigel, president of the Bavarian Academy of Sciences, by whose kindness the most excellent arrangements were made for saving Professor Learned's time and labor in local researches. For instance, when he was in Munich, working through the materials in the Reichsarchiv, the Bavarian Staatsarchiv, and the Kreisarchiv of the place, those pertinent to his subject in most of the other *Kreise* of Bavaria were sent thither for his examination. In the Staatsarchiv in Berlin he had the opportunity to do much of the work needful to be performed in or in respect to the sixteen other Prussian state archives. His local searches, in the six months which he has been able to give to the work, March to September, extended as far east as Danzig and Königsberg, and southeastward into Saxony and Silesia, but were mainly conducted in the provincial and local archives of western Germany, the region from which the earlier German emigration to America mostly flowed, from the archives of Colmar, Stuttgart, and Nuremberg to those of Cologne and Düsseldorf. Before his return voyage he examined also the archives of two of the three imperial Free Cities, and made provision for a proper inventory of the third. His report has not yet been presented. But his letters

(each person engaged in foreign researches sends monthly reports of progress to the Director) warrant the expectation of an abundant harvest.

There is more than the usual prospect that the systematic description of materials which that report will present will be immediately followed up by fruitful studies of a monographic character, because of the active manner in which the general subject is being at present pursued, by individuals and by organizations such as the Pennsylvania German Society. Indeed, the fact that it was being so actively pursued, yet without the systematic archive-work which should properly precede, was one reason why this expedition on the part of the Carnegie Institution of Washington was resolved upon at the present time. A public-spirited member of the society named supplied Professor Learned with a special fund to be applied to any purpose connected with his mission which the Department might approve. At our suggestion it was devoted to procuring for the society photographs of early documents which he should select from among the most important of those he found.

Professor Andrews spent the summer in London and did all that could be done to finish the recasting of his "Guide to the materials for American history to 1783 in the Public Record Office," a recasting made necessary by official action in reclassifying the Colonial Office papers, the chief section of his work, and the Home Office papers. But his efforts to bring his long task to a conclusion have again been frustrated, not only by the fact that this reclassification, begun two years ago, is not yet completed, but by further official decree that the Treasury section and that of the High Court of Admiralty shall be reclassified. The book must obviously wait till it can be brought into accord with the new system. Much sympathy must be felt for Professor Andrews, who will in the end have been compelled to reconstruct nearly every section of his manuscript, and who has already devoted to it more time than a scholar of his eminence would ever willingly devote to the details of such a task.

Prof. W. H. Allison's inventory of Protestant manuscript materials for the religious history of the United States, especially those in the archives of denominations and missionary organizations and in the libraries of theological schools and denominational colleges, was reported a year ago as nearly finished. Unfortunately the duties of his new position at Bryn Mawr gave him little chance to work upon it during the ensuing academic year. Attacking it again this summer, he has now nearly finished it. It presents data from nearly all the significant collections in the country. Those from depositories east of the Mississippi and north of the Potomac rest on careful personal examination. In the case of only one collection known to be of value has access been denied.

Bringing material together from repositories which, on the whole, are much less known to historical students than public archives and the libraries

of historical societies, the inventory should be of great service if the importance of the subject is properly appreciated and if it is properly followed up by documentary publications on the part of the various denominations. Proper estimate of the subject depends on the perception that American religion has been chiefly an affair of the laity, and therefore pervades our social and intellectual history; if in any age or time ecclesiastical history can be properly treated as merely the history of ecclesiastics, it is not so with the history of the United States.

As to the publication of volumes of texts illustrating our religious history, it is a duty which should be most seriously felt by our Protestant theological seminaries. Relatively to what they have to do and to the cost of doing it, the older among them are notoriously the richest general institutions of their respective churches, and their work stands nearest to the denominations' higher intellectual life. The volume now spoken of was planned largely in order to give them the opportunity to engage in broader documentary historical work. At the present time both the Catholics and the Jews of America surpass the Protestant denominations in such scientific services to American religious history.

Besides the two manuscripts already mentioned as having been finished, those of Messrs. Fish and Allison, the Department has in final form that of a "List of documents from Spanish archives, relating to the history of the United States, which have been printed or of which transcripts are preserved in American libraries." This work was begun nearly four years ago, as a natural complement to Professor Shepherd's "Guide to the materials in Spanish archives for United States history." The first part of the work was performed by Miss Mary F. Griffin. After her resignation, little was done upon it until this last December, when it became possible to utilize for its completion the expert knowledge of Dr. James A. Robertson, joint editor of the documentary series called "The Philippine Islands." He has devoted most of the past nine months to completing it, chiefly in the Library of Congress, but also in the New York Public Library and those libraries of Boston and Cambridge in which Spanish transcripts falling within the scope of the work were found.

The volume is intended to include a mention of every document derived from any Spanish archive which relates to the history since 1512 of any portion of the continental United States. The material is arranged chronologically, in two divisions, the one listing those documents which may be found in print, the other those which may be found in the shape of transcripts in any accessible collection in the eastern part of the United States. The great collection of Spanish transcripts in the Bancroft Library at the University of California is understood to be not yet in shape for complete listing or convenient use.

Theoretically every guide to materials in a remote archive should be accompanied by such a list. If we wish to make it easier for the American investigator to locate those documents important to his purpose which can be found only in that far-off repository, much more should we tell him of those which he can use without leaving his study or the nearest library, or those of which good copies can be consulted somewhere in his own country. Not all copies are good, not all printed texts supersede perfectly the manuscript; the student may still prefer to resort to the latter, but he is entitled to know of the existence of the former. It will not often happen that lists of them can be constructed with the thoroughness which Dr. Robertson has bestowed upon this. In the English, perhaps in the French, case the enormous extent of the material would give pause to one planning such a compilation. But taking this Spanish volume as it is, its value to history is plain. Quite apart from its use by those intending to inspect or to send for documents in Spanish archives, such a list of accessible original materials for the history of our relations with Spain and of the Spanish portions of our territory will be indispensable to all the growing number of those who engage in serious study of those subjects.

Last year's report mentioned the beginning of work upon a proposed calendar of papers in Washington archives relating to the Territories. From the opening of the present calendar and fiscal year large progress was made upon it, the compiler being Mr. David W. Parker. It is, of course, the earlier history of the Territories, so important to Western historical societies and workers, that we are anxious to illustrate. It is not needful to carry the search beyond 1873, the year in which the administration of the Territories was assigned to the Department of the Interior; after that date, printed reports abound. Neither is it contemplated—too large a project—to include every paper in Washington archives relating to anything that happened in any Territory—Indian papers, military papers, and the like. By Territorial papers, or papers relating to the Territories, the volume will mean such papers as concern the administration of the Territories as such, or their relations as Territories to the Federal Government. Such papers, anterior to 1873 in date, are chiefly to be found in four places—the Bureau of Rolls and Library in the Department of State, the Bureau of Indexes and Archives in the same Department, the files of the Senate, and those of the House of Representatives.

Mr. Parker labored at the Department of State from January to June, finding great masses of papers, of which the majority had probably never been used by any historical inquirer, and finding also that the old arrangement and binding of the papers was marked by so many eccentricities, even in the matter of distribution between the two Bureaus named, that even for the Territorial papers in the Department of State alone a calendar was a prerequisite to successful historical use. In June, when the work in that Department was

finished, the Clerk of the House of Representatives kindly gave the necessary permission for the examination of its files. But Mr. Parker had then to return to Canada, and a large part of the files are stored where no one could endure to work long among them in the heat of the Washington summer. The work was therefore interrupted at this point, and it does not now appear that it can be resumed till the appropriations for the year 1910 become available.

This may be the most appropriate place at which to mention, what apparently was omitted from record in the last report, that on December 14, 1907, President Roosevelt issued the following executive order, which has been found to facilitate considerably the work of the Department:

> Officers in the executive departments who have charge of archives or administrative records are instructed, in so far as public interests and departmental orders permit them to do so, to allow agents of the Department of Historical Research of the Carnegie Institution of Washington, bearing proper credentials from the Director of that Department, to have access to those papers, for historical purposes, at all times which are not inconvenient in respect to public business, and under such proper conditions as may be desired.

TEXTUAL PUBLICATION OF DOCUMENTS.

The series of Letters from Delegates to the Continental Congress, under the editorial care of Dr. Burnett, has advanced by several steps. The search for letters has been carried on in Maine, New Hampshire, Pennsylvania, Maryland, and partially in New York; when New York is completed, New Jersey will be the only State remaining. The copying of the desired letters or extracts has been completed in Washington, and in Maine, New Hampshire, and Massachusetts, and partly carried out in New York; in Rhode Island, Connecticut, Virginia, North Carolina, and Georgia it had already been achieved. Those extracts which have to be copied from printed books have mostly been copied. The series may therefore be regarded, so far as its texts are concerned, as well advanced toward completion.

The series of treaties between European powers having a bearing on the history of the United States is complete so far as the texts are concerned, but the main work is that of supplying to each document its proper introduction and annotations, which must of necessity traverse a great part of the complicated history of European diplomacy from the Renaissance to the present time. The work begins with the Papal bulls of the fifteenth century, documents which on account of the international position accorded to the Popes before the Reformation have historically the status of treaties. Miss Davenport, the editor of the work, has completed the introductions and notes for the bulls and treaties down to 1632.

Prof. William R. Manning, of the George Washington University, has continued through a large part of the year the search through printed books

in the Library of Congress, with some volumes borrowed from elsewhere, for original materials for the debates in Parliament on American matters. Most of the large collections of debates have now been worked through, and a good deal of progress has been made in the slower task of searching volumes which are not primarily devoted to such material, but in which a greater or less quantity of it may be expected to be found.

MISCELLANEOUS OPERATIONS.

As heretofore, the editing of the American Historical Review has been carried on in the office of the Department and by its staff. Mr. Leland has prepared the annual summary of American historical progress appearing in the Jahresberichte der Geschichtswissenschaft and a similar biennial survey for the Revue Historique. In Paris he has performed various services to organizations needing extensive series of copies or desiring to place orders for work of peculiar difficulty, such as the reproduction of ancient maps in color. Instances which may be mentioned are those of the Department of Archives and History of the State of Mississippi, the Missouri Historical Society, and the Library of Congress, for which it is a pleasure to do anything that can in a slight degree requite our numberless and constant obligations to its librarian and staff.

In the last weeks of the year reported upon, an interesting movement of cooperation among historical societies and institutions was inaugurated, in the preparation of which Mr. Leland and the Director of the Department have for some time been concerned, and which has a close relation to the work of the former in Paris. The usual reasons for seeking to promote cooperation among American historical societies are greatly reenforced in the case of those of the Mississippi Valley by the fact that all that region, though now divided into separate States, was in the earlier period of its history an undivided area under the rule of France. Its earlier history is therefore a matter for joint attack. If in the exploiting of the French archives for Western history each State or State historical society should proceed independently to search for and copy the papers relating to its particular history, or, as is much oftener the case, relating to its history because bearing on the history of the whole region in general, the result would be an indefinite amount of wasteful duplication. Efforts, encouraged by this Department in every possible way, have been for some time in progress, to secure avoidance of this waste by concerted operations on a systematic plan. At its annual meeting of 1907, the American Historical Association provided for a committee on cooperation of this sort, with Dr. Dunbar Rowland, Director of the Department of Archives and History in the State of Mississippi, as its chairman.

The committee naturally concluded that all copying and printing of documents in the French archives ought to be postponed till we should have a

completer knowledge of their contents for American history, and that, the logical first step being the preparation of Mr. Leland's general Guide to the Materials for American History in the Archives of Paris, the second should properly be, for the region of the Mississippi Valley, the making of a comprehensive and detailed calendar of individual documents.

Acting on the basis of a report prepared by Mr. Leland, the committee prepared a scheme, which was adopted at the annual meeting of the Association in December, 1908. Efforts were then begun to secure the subscriptions needful for carrying out the work. In October, the necessary sum was reported to be all subscribed, the subscribers being the Departments of Archives and History in Mississippi and Alabama, the Howard Memorial Library in New Orleans, the Missouri Historical Society, the Kansas State Historical Society, the State Historical Society of Iowa, the Illinois State Historical Library, the Chicago Historical Society, the Indiana Historical Society, the Wisconsin State Historical Society, and the Michigan Pioneer and Historical Society. Work was at once begun in Paris upon the enterprise, which will be under the general charge of Mr. Leland, who is obviously in a peculiarly good position for managing it. His supervision will constitute this Department's contribution to the undertaking. It is very gratifying that the second stage in archive-exploitation, that of calendaring, should in the case of this important body of material have followed so closely upon the first; and, in view of the activity of the Western historical societies and workers, one can not but feel sure that large results will flow from the eventual publication of the calendar.

Mr. Leland has also devoted a small part of his time in Europe, when official journeys made it possible, to study of archive-systems and buildings, and a large part of his time in America to his new duties as secretary of the American Historical Association. Miss Davenport spent a part of her time in the spring in the preparation for that society of a descriptive list of the materials for English diplomatic history in the modern period, a contribution to the bibliographical work on modern English history which the society is planning to carry out, with English aid.

As in previous years, searches and copies have been made by the Department, or under its supervision, for organizations such as the Illinois State Historical Library and various historical societies, and for many individuals. Letters of inquiry as to historical papers in Washington and other matters have been answered with great freedom. The Director has, as a matter of course, done what he could in small miscellaneous ways to further the interests in Washington of the American Historical Association and of American historical scholars.

PLANS FOR 1910.

The continuance of the various pieces of work now in progress must naturally constitute the main portion of the work of the Department for next year.

REPORTS, AIDS, AND GUIDES.

The first place naturally belongs to the printing and publication of the works by Messrs. Bolton, Fish, Allison, and Robertson, already described as nearly or quite completed in manuscript. It will be expected that Mr. Learned will be able by the end of the academic year to submit the manuscript of his report on his German expedition. Mr. Andrews will do all that the progress of reclassification in the Public Record Office permits him to do toward finishing his Guide to the materials for American history to 1783 in that repository. Mr. Leland will proceed to Paris as early as possible in the spring, to deal with the materials yet remaining and with those which, as has been mentioned above, have been newly thrown open to public examination. Mr. Parker, or some one else if his relations with the Canadian archive establishment make him unavailable, will complete the calendar of Territorial papers by examination of those which are preserved in the files of the Senate and House of Representatives.

In the place of the enterprises which have been completed or are nearing completion, I should wish to begin three new undertakings.

In the first place, a report on the materials in London archives for American history since 1783 is the natural complement to those which have been prepared on the earlier period. From the recognition of American independence by Great Britain in 1783 the materials for American history in her archives take on naturally a different character, making 1783 an obvious dividing-point in the subject-matter. The center of interest shifts from the Colonial Office to the Foreign Office papers. In the latter, the diplomatic relations between Great Britain and the United States can now be studied, by persons properly introduced, down to at least the year 1848, a period of sixty-five years. That those relations constitute an important part of American history needs no demonstration, and excellent students are beginning to deal with them. Other aspects of Anglo-American relations, both in times of war and in times of peace, are illustrated by large masses of material in the War Office and Admiralty papers, while our relations to Canada and to other American colonies retained by Great Britain give value to considerable portions of the Colonial Office papers.

Fortunately the process of reclassification has been carried through with respect to nearly all the Public Record Office material which would be dealt with in the proposed manual, so that there would be no need to apprehend embarrassment or delay from this source. Minor archives would, for this

modern period, contribute much less than they did to the volume of Professor Andrews and Miss Davenport for the colonial and revolutionary time. The bulk of the work would lie in the four collections of material, or sections of the Public Record Office, named above.

I desire to be permitted to secure for this work in 1910 the services of two gentlemen, expert respectively in the history of the diplomatic relations between Great Britain and America and in our naval and military history, Prof. Frederic L. Paxson, of the University of Michigan, and Dr. Charles O. Paullin, of Washington, formerly of the Navy Department. Three months of the former's time and five months of the latter's would be available. In that time it should be possible for them, working in concert, to collect the data for an adequate manual of the kind referred to, and of the same general character as Professor Andrews's Public Record Office volume. The material lies, more largely than is the case for the period before 1783, in continuous deposits of related official material, more easily described than, for instance, the more casual accumulations of the British Museum.

Secondly, I should wish in 1910 to make some preparations toward a similar book for the archives of Canada. I believe that country to have the next most important archives, for our purposes, to those to which we have already sent expeditions—England, Spain, France, Mexico, Rome, and Germany. First of all, there are the materials collected by the archives office of the Dominion at Ottawa. For nearly forty years, under very energetic administration, that office has been making itself an enormous repository of copies from the British and French archives, and students from the United States have been resorting to it for consultation of British and French papers relating to our colonial period. This portion of the collection has been so largely covered by calendars published in the annual reports of the Archive Branch, and a full description of it would so largely duplicate our London and Paris volumes, that in a future "Guide to the materials for United States history in Canadian archives" the section devoted to it would be a minor affair, the preparation of which would not be troublesome. But the archives have always contained a certain amount of what may be called material indigenous to Canada, not copied from London, and also not usually represented by copies in London. A few years ago the amount of this was enormously increased by administrative orders which transferred to the custody of the Archivist and Keeper of the Records the earlier or non-current portions of the papers of the several executive departments. These, which had up to that time remained, after the custom prevalent in Washington, in the charge and buildings of the several offices of federal administration, have now become parts of the general archives of the Dominion, gathered or to be gathered into its excellent new archive-building at Ottawa. Mostly inaccessible hitherto, they have hardly been touched by historical scholars from the United States, yet are reported to be rich in material for their uses.

A Guide to the Canadian archives composed from our point of view would, so far as Ottawa is concerned, have a general resemblance to Van Tyne and Leland's "Guide to the Archives of the United States Government," the second edition of which was published by us in 1908, but with such differences as would arise from the partial concentration of records in a general archive, which we do not yet have in Washington. But it should also embrace the archives of the component provinces of the Dominion. The archives of the Maritime Provinces, at Halifax, Fredericton, and Charlottetown, especially the first, are rich in material for the history of New England, both because of nearness and close political relations and because of the Loyalist migration. Similar causes give importance to those of Ontario, at Toronto, while the civil and ecclesiastical archives of Quebec, so far as preserved and available, are well known to abound in instruction for earlier periods. So many questions of method arise in connection with a composite task like this, questions which can only be answered by careful inquiries and preliminary investigations, that only an appropriation sufficient for tentative beginnings has been asked for.

The third request has been shaped in the same spirit. No doubt is felt that a scientific atlas of the historical geography of the United States is greatly needed, and little doubt that the task is especially incumbent upon our Department. To make a good historical atlas involves expense beyond the power of individuals. Governments, on the other hand, usually find themselves restrained by political considerations, or by the positions they have taken in international and other discussions, from publishing maps and letterpress which treat questions of historical geography with perfect scientific detachment, and display the facts as they might appear to a Martian rather than as they ought to appear to an American. An endowed historical department in Washington, enjoying the good-will and the frequent assistance of Governmental bureaus, is in an ideal position for producing such an atlas of American historical geography as is desiderated.

But the construction of such an atlas is not a task to be entered upon without deliberation, many calculations, and the best advice, nor to be proposed to Trustees before the project has attained the most definite and concrete shape, with abundant details as to contents and cost. This is especially true if the plan when fully developed will, as is hoped, be marked by an unusual development on certain sides. The stock varieties of maps in historical atlases are: maps which illustrate boundaries and divisions existent in different periods, and those which illustrate particular historical events, such as campaigns and battles. There should be no disposition to neglect such categories as these. Maps illustrating the territorial claims of European powers, the grants made by them, the boundaries of colonies and states, the acquisitions and boundary disputes of the United States, and the like mat-

ters, should appear abundantly, and so should maps, or reproductions of old maps, showing the gradual development of knowledge of the Atlantic and other coast-lines. But also, in the case of a country like the United States, much more should be done than has ever before been done in any national historical atlas to illustrate cartographically the progress of economic and social development. This is the most significant aspect of American history, and one certain to receive increasing attention in the decades immediately following the present. Maps illustrating the progress of settlement, the growth of population, the progressive occupation of the land, the history of land-policy, the history of industries, the history of slavery, the history of wealth, the history of routes and transportation, of religion, of political opinion, should all have their place in such an atlas, in so far as without undue expense it shall prove possible to secure, for these varied phenomena, graphic methods of representation that are scientific in character, securely based, and not misleading.

But all this means not only the application of much historical scholarship to the conventional lines of American historical geography, but also the application of much thought and ingenuity to the historical questions and the cartographical problems lying in these newer fields. It means, therefore, the enlisting of varied cooperation and the incurring of relatively large expense. It is deemed premature to ask for present consideration of the question whether such an undertaking shall ever be entered upon. But it is deemed distinctly appropriate, in view of the pressing importance of the general idea, to ask now for the means of putting that question in an answerable form, of taking advice as to what the enterprise should include, of collecting information as to what it would cost under various possible forms, and of drawing up for subsequent consideration a concrete, detailed, and practicable project. Accordingly, a preliminary appropriation, for defraying expenses of consultation, has been solicited.

TEXTS.

It should be possible within the year 1910 to complete the texts of the Continental Congress volumes, and to begin their annotation; to complete to a relatively late date the introductions and annotations to the European treaties relating to America; perhaps to finish the collecting of material, so far as it can be collected in this country, on the American debates in Parliament; and certainly to begin the copying of the American material already listed in the Commons Journals.

MISCELLANEOUS OPERATIONS: DEPARTMENT BUILDING.

The Department will no doubt maintain in 1910 activities similar to those described under this head above, in the report concerning the past twelve

months. Aside from these, the main matter to be mentioned in this concluding section of this report is, as in last year's report, the need of an adequate building for the Department. Its new quarters in the Bond Building are better than the old, but are still unsatisfactory in location, especially on account of their remoteness from the Library of Congress. The greater part of our historical work is done in that library, and most of our staff, except the Director and those occupied with clerical work, spend most of their time in it and in going to it and coming from it. Now that the administrative offices of the Institution have been removed to the new building on Sixteenth Street, the one merit which our present location possessed has disappeared. On this vitally important matter of a better location, I beg leave to refer to my report of a year ago, in which the need is more fully set forth.

PLATE 7

FLEET OF THE MARINE BIOLOGICAL LABORATORY, TORTUGAS, FLORIDA.

DEPARTMENT OF MARINE BIOLOGY.*

Alfred G. Mayer, Director.

In March, 1909, the Director went to Jamaica, visiting Kingston and Port Antonio. The Scyphomedusæ and Ctenophoræ of the region were studied and some general collecting was conducted in order to reveal the relative merits of Jamaica and the Tortugas as centers for research in marine biology. The coral reefs of Tortugas are far more extensive and better endowed with life than are those of Jamaica, the climate is cooler and more healthful, and the pelagic fauna of Tortugas is certainly as rich as that of Jamaica, if not richer. On the other hand, the varied land fauna and flora of Jamaica set it apart from Tortugas in its superiority, and there are also a few marine forms to be had locally at Jamaica which do not exist at Tortugas; so that for the prosecution of certain special researches Jamaica affords facilities which are probably unrivaled in the West Indies. The scientific success of every marine laboratory is dependent upon the study of animals which may be obtained in abundance in its immediate vicinity, and thus the local element is by far the most important factor to be considered in the determination of the site for a marine station. Judged in this wise, we have reason to congratulate the Institution upon the selection of the Tortugas as the site for a station from which to study the West Indian fauna. Dr. R. Hartmeyer, of Berlin, who has collected extensively over the West Indies, speaks highly of the richness of the Tortugas fauna in his recent paper "Die westindischen Korallenriffe und ihr Tierleben," in Meereskunde, Berlin, Jahrg. 3, Heft 2, 1909.

The hull of the dory launch *Porpoise* having become relatively unseaworthy through constant use for the past five years, it was deemed expedient to replace her by another boat, for upon collecting expeditions in the neighborhood of Tortugas our vessels are often obliged to encounter heavy seas and sudden squalls of tropical violence. Accordingly, a new launch, the *Velella,* was made for the Laboratory by the Miami Yacht and Machine Company. This new boat is 25 feet long and has a 12-horsepower, double-cylinder engine, so that she is capable of making 9 miles an hour in smooth water and is one of the most essential of the Laboratory vessels. The old launch *Porpoise* is still in service for collecting trips in the immediate neighborhood of the laboratory.

A considerable addition was made to the eastern side of the Laboratory to improve the sleeping accommodations and to cool the air which enters the laboratory itself. In order still further to reduce the temperature, 10 tons

* Situated at Tortugas, Florida. Grant No. 541. $15,000 for investigations and maintenance. (For previous reports see Year Books Nos. 3, 4, 5, 6, and 7.)

of earth from New Jersey were taken to Tortugas, and such of it as was not required for the rearing of *Solanum* for Professor Tower's experiments was spread over the ground in order to form a soil for the cultivation of attractive flowering plants, such as *Hibiscus, Bougainvillea, Poinsettia, Coleus,* etc. Hitherto the laboratory has been surrounded by barren shell-sands of almost alabaster whiteness, the heat and glare of which rendered out-of-door excursions most uncomfortable. We hope that in a few years the buildings may be embowered in a beautiful tropical garden, for, as Professor Dohrn once told me, the success of his great zoological station at Naples is in no small measure due to the sublime beauty of its surroundings. The station of the Tortugas Laboratory is unique in the tropics for its cleanliness and healthfulness, and we shall now aim to render it equally attractive for its beauty, for it is only under the best conditions of life that the best results from the arduous labor of research may be obtained.

The Tortugas Laboratory is a summer school of research where all are students, for the relation of master and pupil is unknown in such a republic of intellectual equality. Its simple object is to render aid to those who have already displayed exceptional ability in the prosecution of research and whose problems may be better studied at Tortugas than elsewhere. There are indeed certain classes of problems in biology, such as those of physiology, embryology, cytology, œcology, heredity, etc., which have not been attempted in the tropics, for the lack of sufficient facilities, and it is the aim of the Laboratory to encourage such studies rather than to lend aid to the gathering of general collections of dead and preserved animals, such as have so frequently been brought into our museums from tropical regions. But special collections by trained students of certain groups of animals are encouraged, for these lead to the discovery of new and interesting forms, and thus to the ultimate possibility of the elucidation of laws of nature.

The success of the Laboratory is due to no one man, but to the combined labors of all those who have honored it by their devotion to its aims, and therefore, after briefly reviewing the work of the present year, we will give a summary of the results which have been achieved by its students during these first five years of its existence.

The following investigators studied at the Laboratory in 1909:

Dr. R. P. Cowles, Johns Hopkins University, June 24 to July 20.
Mr. E. Newton Harvey, University of Pennsylvania, May 25 to July 25.
Prof. Seth E. Meek and his assistant, Mr. William Heim, of the Field Museum, Chicago, May 8 to 22.
Prof. Henry S. Pratt, Haverford College, May 25 to June 29.
Prof. Charles R. Stockard, Cornell Medical College, May 12 to June 21.
Prof. W. L. Tower, Chicago University, May 3 to 10, July 20 to 23.
Prof. David H. Tennent, Bryn Mawr College, May 25 to July 20.
Prof. Aaron L. Treadwell, Vassar College, May 25 to July 12.
Dr. T. Wayland Vaughan, U. S. Geological Survey, May 2 to 22.

All of these investigators returned north in excellent health, and in this connection it is interesting to observe that since the pure-food law went into effect we find that indigestion and other troubles have disappeared, although these were formerly more or less prevalent where we must, as at Tortugas, depend mainly upon canned foods for our supplies.

Commodore William H. Beehler, U. S. N., commandant of the naval station at Key West, has been unfailing in his generous interest in the station and has, as in the past, been ever ready to offer aid to us upon all occasions.

During the year the first two volumes of "Papers from the Tortugas Laboratory" were published as Publications 102 and 103 of the Carnegie Institution of Washington. These volumes contained the following papers:

Volume I.

Jordan, H. E. The germinal spot in echinoderm eggs. 12 pages.
Jordan, H. E. The spermatogenesis of Aplopus mayeri. 24 pages, 5 plates.
Jordan, H. E. The relation of the nucleolus to the chromosomes in the primary oocyte of Asterias forbesii. 36 pages, 7 plates.
Brooks, W. K. Pelagic Tunicata of the Gulf Stream: Part II, Salpa floridana. Part III, The subgenus Cyclosalpa. Part IV, On Oikopleura tortugensis, a new Appendicularian from the Dry Tortugas, with notes on its embryology. 16 pages, 8 plates.
Brooks, W. K., and B. McGlone. The origin of the lung of ampullaria. 8 pages, 7 plates.
Mayer, A. G. The annual breeding-swarm of the Atlantic palolo. 8 pages, 1 plate.
Mayer, A. G. Rhythmical pulsation in Scyphomedusæ. 18 pages.
Perkins, H. F. Notes on medusæ of the western Atlantic. 24 pages, 4 plates.
Linton, Edwin. Helminth fauna of the Dry Tortugas. 34 pages, 11 plates.
Edmondson, C. H. A variety of Anisonema vitrea. 1 page.

Volume II.

Cowles, R. P. Habits, reactions, and associations in Ocypoda arenaria. 41 pages, 4 plates.
Stockard, C. R. Habits, reactions, and mating instincts of the walking-stick. 17 pages, 3 plates.
Stockard, C. R. Studies of tissue growth: I. An experimental study of the rate of regeneration in Cassiopea xamachana. 42 pages.
Zeleny, Charles. Some internal factors concerned with the regeneration of the chelæ of the gulf-weed crab. 36 pages.
Chapman, F. M. A contribution to the life-histories of the booby and man-o'-war bird. 13 pages, 6 plates.
Conklin, E. G. The habits and early development of Linerges mercurius. 18 pages, 8 plates.
Conklin, E. G. Two peculiar actinian larvæ from Tortugas, Florida. 16 pages, 4 plates.
Watson, J. B. The behavior of noddy and sooty terns. 69 pages, 11 plates.
Reighard, Jacob. An experimental field-study of warning coloration in coral-reef fishes. 69 pages, 5 plates.

In addition to the above, the following were published elsewhere during the year:

Stockard, Charles R. Inheritance in the "walking-stick" Aplopus mayeri. In Biological Bulletin, vol. 17, pp. 239–245, 3 figs. 1909.
Also: Studies of tissue-growth. II. Functional activity, form regeneration, and degree of injury as factors in determining the rate of regeneration. The reaction of regeneration upon the old body. In Journal of Experimental Zoology, vol. 6, No. 3, pp. 433-469, 1 plate. 1909.

Hartmeyer, R. Die westindischen Korallenriffe und ihr Tierleben. In Meereskunde, Jahrg. 3, Heft 2, Berlin, 40 pp. 1909.
Mayer, A. G. On the use of carbon dioxide in killing marine animals. In Biological Bulletin, vol. 16, p. 18.
Also: On the use of magnesium in stupefying marine animals. *Ibid.*, vol. 17, p. 341, 1909.
Also: The relation between ciliary and muscular movement. In Proc. Soc. Experimental Biol. and Medicine, vol. 7, 1909.

Messrs. McClendon, Hooker, Hargitt, and Stockard have presented papers for publication in the forthcoming volume 3 of Papers from the Tortugas Laboratory of the Carnegie Institution of Washington, and other articles are being prepared by Messrs. Cowles, Harvey, Linton, Osburn, Stromsten, Tennent, Vaughan, and the Director, and thus material for at least one more volume is assured.

We now present the preliminary reports of this season's studies:

PRELIMINARY REPORTS OF RESEARCHES, SEASON OF 1909.

Preliminary Report on the Behavior of Echinoderms, by R. P. Cowles, Johns Hopkins University.

During the summer of 1909 the study of the behavior of Echinoderms, begun in 1905, was continued. A special investigation was made of the reactions of *Echinaster crassispina* to light, of the factors determining the method of righting, and of locomotion. The following is a brief statement of the results:

(1) *Echinaster* in locomotion does not show any tendency to use a special ray, or pair of rays, as directors.

(2) With fresh material, and with the light excluded, it was found that different individuals of *Echinaster* which had been inverted did not right themselves on the same pair of rays. It was also found that in long series of trials repeated day after day the pair used the majority of times on one day was often not the same on succeeding days. The experiments did, however, make it clear that an individual sometimes shows a decided tendency to right itself on a certain pair of rays. Fatigue, unhealthy conditions, and injury are important factors. My experiments lead me to believe that the behavior with reference to the rays used in righting is controlled by physiological conditions rather than by structural ones.

(3) The direction of locomotion just before a trial in righting takes place does not seem to influence the selection of the pair of rays used in the righting.

(4) The tilt of the bottom upon which the starfish is lying, when small, does not affect the selection of the rays in righting; but when the angle is 10° or more, there is a tendency for *Echinaster* to right itself down-hill irrespective of the rays used. (Light excluded.)

(5) Ophiuroids and some starfishes which are considered as "negatively phototactic" to daylight right themselves away from the source of light. This one would naturally expect. *Echinaster* and probably other starfishes which are considered as "positively phototactic" to daylight also right themselves away from and then move toward the source of light. This phenomenon is

hard to explain, unless it be assumed that the oral surface is much more sensitive to bright light than the aboral surface.

(6) The above explanation receives support from a series of experiments showing that when the intensity of the light is reduced—*i. e.*, much less than ordinary diffuse daylight (about 10 candlepower)—the tendency to right away from the source of light is not nearly so strong.

(7) *Echinaster* tends to right itself away from the light even though in so doing it has to turn up a slightly inclined plane (4° 30′).

(8) While all my experiments lead to the belief that the direction of locomotion of *Echinaster* is determined by the relative intensity of the light rather than the direction of the rays, yet a series of experiments were undertaken using a special apparatus into which was admitted light of a graded intensity. Many trials with this apparatus showed conclusively that *Echinaster* moves from place to place guided by the relative intensity of the light striking the different parts of the body and not by the direction of the light rays.

(9) A change of temperature does not change the sign of the reaction to a source of light. *Echinaster* moves toward the source of light when the temperature is kept anywhere between 64° and 94° F. At the two extremes, however, the response is very weak.

(10) Experiments made with various color-screens indicate that no one kind of ray is necessary to stimulate *Echinaster*. The following five screens used cut out: (*a*) ultra violet; (*b*) ultra violet and violet; (*c*) violet and blue; (*d*) green, yellow, orange, and red; (*e*) ultra red.

(11) When the tip of each ray is amputated, this starfish still rights itself away from the source and then moves toward the source of light, just as in normal individuals. This shows that the eye-spots are not necessary in the reactions of *Echinaster* to light.

A detailed account of the experiments upon which the above conclusions are based, together with an account of experiments using the starfish *Astropecten duplicatus* and the ophiuroid *Ophiocoma riisei*, will soon be published by the Carnegie Institution of Washington.

Preliminary Report of Researches at Tortugas, June and July, 1909, *by E. Newton Harvey, University of Pennsylvania.*

(1) The Temperature Coefficients of Some Life Processes, and the Effect of Electrolyte Solutions on the Medusa Cassiopea at Different Temperatures.

A study was made of the pulsation-rate and the rate of nerve-conduction in *Cassiopea xamachana* at different temperatures. Before beginning this work, the upper and lower temperature-limits of muscle-contraction, nerve-conduction, and the origination of pulsation in the sense-organs were determined. All of these can be very readily separated in this animal. It was found that contraction stops at 10.6°, conduction at 9.5°, and pulsation at 14° to 15°. This stoppage is reversible to about 7° to 8°, when the tissues do not recover, but disintegrate on warming. This adds another example to the list of irreversible changes occurring in tissues at low temperatures but above the freezing-point. The upper temperature limits are 39.5° for muscles, 44° for nerves, and 42.6° for sense-organs. At 44.5° recovery of conduction does not occur on cooling. There is evidence that all the above temperatures are a function of time and the condition of the medusa, so they can only be approximate. The temperature of the water in which *Cassiopea* lives varies not more than 3° either side of 30° C. in summer.

This jellyfish is quite sensitive to shocks and to slight changes in temperature, so that an accurate temperature-pulsation curve could not be plotted. Enough data were obtained to show that the pulsation-rate follows a chemical temperature coefficient (about 3 for 15° to 25° and 2 for 20° to 30°). This was to be expected, as other rhythmical tissues have been shown to behave similarly.

In 1906 Mayer* discovered that a ring-shaped piece of tissue could be so stimulated as to entrap a conduction wave which travels around the ring in one direction, stimulating the muscles as it goes. The rate at which this travels is so regular that it offers a favorable object for the study of nerve-conduction at different temperatures. It is difficult to start a wave at low temperatures, but a curve between 18° and 38° was obtained. It is a right line to 29°, then a gradual falling off to a maximum velocity of propagation at 33°, and then a diminution of rate with increasing rise of temperature. The increase in rate for 10° indicates a chemical change as the basis of conduction.

The effect of solutions which stop contraction and conduction was tried at different temperatures 10° apart to determine if the solutions acted in a chemical way (as formation of ion-proteids) or in a physical way (as change in surface tension). Owing to the difficulty of obtaining and keeping ice at Tortugas, only a limited number of experiments could be performed.

Temperatures of 24° to 34° were used in order to have the conditions as near normal as possible, and ⅜ *m* $MgCl_2$ was tried first. At 34° the power of contraction and conduction was stopped about 2 to 2.5 times as soon as at 24°. This indicates a combination of Mg with some muscle constituent, perhaps an Mg-proteid, and that the reaction velocity of this particular reaction has a temperature coefficient of about 2.5. The reverse experiment gave a very peculiar result. The strips of tissue were first placed in ⅜ *m* $MgCl_2$ at 29° for a certain time, then removed to sea-water at 24° and 34°. The nerves always recovered instantly (< one-half minute), the muscles in times which indicate only a partial chemical temperature coefficient for one set of muscles. This can only be made clear by actual data which will be given in the complete paper. Here, then, is apparently a reversible process which proceeds in one direction with a chemical temperature coefficient, while in the reverse direction it is instantaneous (in the case of nerve-conduction), slow, but not following definitely a chemical temperature coefficient (in the case of muscle contraction).

A few experiments, with 20° to 30° as the 10° interval, gave quite different results. Contraction was stopped at about the same time in the two solutions, in some cases sooner, at 20°. Experiments in sea-water at 34° and 22° showed that contraction is not so vigorous as at 34°, and I am inclined to believe that this might so lessen the time of activity in $MgCl_2$ at 20° as to mask the chemical temperature coefficient. In other words, we are dealing with a double effect.

Similar experiments with CH_3COOH gave essentially similar results. Experiments with chloroform sea-water gave rather indefinite results. I hope to continue these experiments on other tissues, perhaps more favorable for temperature experiments than those of tropical animals.

* Carnegie Institution of Washington Publication 47, 1906.

The rate at which nerve-conduction decreased in velocity in $MgCl_2$ and CH_3COOH was also studied to determine if it followed a logarithmic curve, which would be the case if the hypothetical Mg-proteid or acid-proteid reaction was a monomolecular reaction following the law of mass action. As yet I have not had time to study the data. A comparison was also made of toxic concentrations of CH_3COOH and HCL.

(2) The Chemical Action of CH_3COOH in Causing Artificial Membrane Formation in Sea-urchin Eggs with Further Experiments on Membrane Formation.

In order to test Loeb's hypothesis that the reason the fatty acids only cause membrane formation in sea-urchin's eggs is because they dissolve out the lipoids, the efficiency of acetic acid at different temperatures was tried. It was found that the time required for the acid to exert its effect was about doubled for every 10° lowering of temperature.

The recent work of Delage* on electric parthenogenesis has made possible an exact comparison of the methods of stimulating contractile tissues (muscles and sensitive plants) and the methods of causing artificial parthenogenesis in various eggs. The various means of stimulating muscles may be roughly classified as electrical, mechanical, thermal, chemical, and osmotic, and these are exactly the heads under which the various means of exciting eggs to develop may be arranged. In a series of recent papers,† R. S. Lillie has shown that the essential effect of stimulation in contractile tissues is an increase in permeability of the plasma membrane, this change allowing the escape of the reaction-products of the reaction on which the energy transformations in contraction depend. This permits the reaction to proceed during contraction, until it is again checked by a second accumulation of reaction-products during rest. Regarding the egg as a system of reacting substances, one would expect these to come to equilibrium at one point in their cycle. This equilibrium is upset, and development proceeds by an increase in permeability of the egg-membrane allowing the exit of some reaction-product (possibly Co_2, as in the case of muscle). Normally, this is brought about by the entrance of a spermatozoon artificially by the various parthenogenetic agents. The recent work of Loeb has shown that many of the substances which cause parthenogenesis are hæmolytic substances, increasing the permeability of blood-corpuscles to such a degree that the hæmoglobin escapes.

With the above idea in mind, a study was made of the process of membrane formation as being the first marked change in the egg after fertilization. Since the egg of the sea-urchin, about six hours after shedding, can be fertilized with foreign sperm, it was thought that the change undergone on standing might possibly be in the direction of increased permeability. Such did not prove to be the case, as it was found that a very slightly longer treatment with CH_3COOH was necessary to produce membranes in eggs which had stood for six hours. If the egg does undergo no change in the direction of increased permeability on standing, this may be connected with the fact that sea-urchin eggs do not develop spontaneously as readily upon standing as do some other eggs.

The process of membrane formation may be divided into two phases, the actual membrane formation and the separation of the membrane from the

* Archiv. de zool. exp. et Gen., 1908. Notes et Revue, p. xxx.
† Especially Am. J. Phys., vol. 24, 1909, pp. 14 to 44.

egg. The latter may be due to the formation of some substance with high osmotic pressure which absorbs sea-water and pushes the membrane outward. Attempts to determine the osmotic pressure of this hypothetical substance with hypertonic sea-water failed because the membrane was very freely permeable to the salts of sea-water. The formation of the membrane appears to be secretory in nature.

It was found that double membranes could be formed by treating sperm-fertilized eggs with $CHCl_3$-saturated sea-water. This took place at the two-cell stage also and less distinctly as far as the early blastula. Attempts to produce double membranes in other ways failed.

Owing to the scarcity of sea-urchins about Tortugas this year, a further study could not be made. Most of the above work on eggs was made possible by two cruises of the *Physalia* to the Marquesas Keys, the experiments being performed on board.

Since this report was written, a paper by R. Lillie (Biol. Bull., vol. 17, page 188, 1909) has appeared in which the same view is supported, namely, that an increase in permeability of the plasma membrane is the essential condition for the initiation of development in an egg.

The Trematodes and Cestodes of Tortugas, by H. S. Pratt, of Haverford College.

During the month I spent at the Marine Biological Laboratory of the Carnegie Institution of Washington at Tortugas, I collected material for the morphological study of the trematodes and cestodes of the region. To obtain the former teleostean fishes and loggerhead turtles were collected, while the cestodes were found in selachian fishes. 74 teleosts belonging to 20 species were investigated and about 30 species of trematodes obtained from them, while 5 species of trematodes were obtained from 2 loggerhead turtles; 7 selachians, of which 5 were sharks and 2 were rays, were investigated and about 10 species of cestodes and 1 of trematodes obtained.

The trematodes in the loggerhead turtles were found in the stomach, duodenum, small intestine (not including the duodenum), and rectum. Three species were obtained from the stomach, one of which belongs to the genus *Plesiorchorus* and is closely allied to *P. cymbiformis,* which occurs in the same turtles in the Mediterranean. Two other species, closely allied to *Cymatocarpus undulatus* and *Rhytidodes gelatinosus* of the Mediterranean turtle, were also found. One of these, the *Cymatocarpus,* was represented by many hundreds of individuals in the duodenum of each of the turtles examined, although *C. undulatus* is rather an unusual form in the Mediterranean turtle, having been found by Looss in only 2 out of 14 turtles examined by him. The anatomy of these chelonian trematodes and their relation to those occurring in other parts of the world will be the subject of a paper which will be published in the near future.

Of the large number of 30 species of trematodes found in the teleostean fishes examined, about 60 per cent occurred in the intestine of their hosts, about 8 per cent in the stomach, 12 per cent in the pyloric appendages, 8 per cent in the duodenum, and 12 per cent in the rectum. These worms were found in most cases in small numbers in their hosts, sometimes but 1 or 2, rarely more than a dozen individuals of a species occurring in a single host. In the few cases in which the individuals of a species were numerous in a single host, the pyloric appendages were usually the seat of the infection.

The trematodes found in these teleosts were further characterized by the extraordinary range of form and structure they exhibited. Many of them belong to new species and some to new genera which have recently been established by Prof. Edwin Linton. Almost all the various subdivisions of digenetic trematodes are present, distomids (including appendiculate forms), monostomids, and amphistomids being all represented. Of special interest also are several species belonging probably to a new genus, which were found in grunts, snappers, sculpins, groupers, and slippery-dicks, and represent apparently intermediate stages between the digenetic and monogenetic trematodes. The anatomy of all these interesting teleostean trematodes and their morphological relationships will form the subject of a paper which will be presented to the Carnegie Institution of Washington for publication.

The species of cestodes found in the selachians examined were mostly identical with those described by Professor Linton in his recently published report on the Helminth fauna of the Dry Tortugas. One new and unusual species, however, was found in the sand-shark, the entire body of which is spinose. A species of monogenetic trematode belonging to the genus *Monocotyle* was also found on the gills of the eagle ray, which is closely allied to *Monocotyle myliobatis,* which occurs on the gills of the eagle ray of the Old World.

Preliminary Report on Studies of Growth, by Charles R. Stockard, Cornell University Medical School, New York City.

Experiments were conducted to further test my previous results pertaining to the influence of newly regenerating tissue on the animal body. The scyphomedusa *Cassiopea xamachana* was used for this investigation. In the first case each of 20 selected individuals had 5 of the 8 oral-arms amputated at their bases; another group of 20 of the same average size also had 5 mouth-arms cut from each individual and in addition a piece was removed from the disk, about one-third of the periphery in length and extending in radially beyond the zig-zag muscular ring. Both groups were thus obliged to regenerate equal numbers of mouth-arms, but the latter had also to grow new disk material to replace the removed strip. Any difference in body size or vigor in the two groups must be caused by the additional growth of disk material imposed upon the latter group, since in all other respects the groups were in an identical condition.

Measurements were made after given periods of time and tabulated. The averages below show the changes in body size in millimeters:

Group.	Average original diameter.	Diameter after 12 days.	Diameter after 20 days.	Diameter after 28 days.	Diameter after 34 days.
Group 1 (5 arms cut) ..	81.5	67.5	59.3	53.5	49.7
Group 2 (5 arms and disk cut)	81.5	64.3	57.6	52.3	48.4

The second group of medusæ, which were regenerating more new tissue, decreased in size more rapidly than the first group during the early 12 days of the experiment. They then decrease less rapidly, so that after 20 days their loss is practically the same as that of the first group. The new tissue was being formed from the old body while the animals remained unfed. The fact

of importance is that the new disk-tissue regenerates rapidly at first and almost completes itself within the first 12 days and then begins to differentiate. After this time both groups are growing only the 5 new arms and so decrease about equally in size. The more tissue the animal is regenerating the more rapidly is its old body-size diminished, and it would finally be emaciated and exhausted by this growth.

The experiment further supplies data bearing upon the influence of the degree of injury on the rate of regenerative growth. The first group has a total amount of injury less than that of the second, yet both groups are growing equal numbers of oral-arms. The table below shows the average length in millimeters of the regenerating arm-buds after given periods of time:

Group.	Arm-buds, 12 days.	Arm-buds, 20 days.	Arm-buds, 28 days.	Arm-buds, 34 days.
Group 1 (disk uucut)..	4.7	5.5	6.3	6.9
Group 2 (disk cut).....	4.1	5.4	6.25	6.9

The arms in both groups are regenerating at equal rates, although one group is more injured than the other. The less injured group regenerated faster than the more injured during the early part of the experiment, but this advantage was later lost. This evidence shows, as did my previous results, that the rate of regeneration is not always influenced by the degree of injury.

A second experiment consisted of 2 groups each of 14 individuals of the same average sizes. These medusæ were operated upon so as to remove the stomach and all the mouth-arms from the first group, leaving only the medusa disk, while 5 oral arms and a part of the disk were cut from the other group in a manner exactly similar to the second group of the above experiment.

The first group regenerates a thin film of tissue to cover the central stomach space. This tissue often tears and reforms several times, then begins to thicken, and finally forms new arm-buds, so that the actual amount of regenerating tissue during the early period of the experiment is more than in the other group. Accompanying this we find a greater decrease in disk diameter in these specimens during the early part of the experiment. Gradually, however, the two groups come to decrease in size at about equal rates, as indicated in the average measurements shown below:

Group.	Average original diameter.	Diameter after 14 days.	Diameter after 22 days.	Diameter after 28 days.
Group 1 (arms and stomach off).....	88.6	62	55.3	51
Group 2 (5 arms and disk cut).....	88	69	63	59

The first group lost 26.6 mm. in diameter during the first 14 days, while the second group lost only 19 mm. From the twenty-second to the twenty-eighth day of the experiment the first group lost 4.4 mm. and the second group 4 mm., about the same in each case. Here again it is shown that while the medusæ are regenerating large amounts of tissue they decrease more

rapidly in body-size than others growing lesser amounts, and therefore the new growing tissue must possess an excessive capacity for the absorption of nutriment and may do so even at the expense and injury of the old body.

EXPERIMENTS TO CONTROL REVERSAL OF ASYMMETRY IN THE REGENERATING CLAWS OF CRUSTACEA.

Five species of the genus *Synalpheus* were used in the experiments. These small crustacea have the first pair of claws dissimilar in size and shape, one claw being large and strongly developed, while its mate is small and weak. Przibram and Wilson found that when the large first claw was removed at the breaking-joint the small claw of the other side grew to be large and a small claw regenerated from the stump of the previous large one; and thus the asymmetry was reversed. The removal of both first claws was always followed by regeneration of the large and small claws on their proper sides. No evidence was found to show why this reversal took place or how it might be prevented.

I tested 50 individuals in order to satisfy myself that the 5 species selected responded to removal of the first legs, as above stated. It was found without exception that when only the big claw of the first pair was removed a small claw always regenerated from its base, while the small claw of the other side grew to be a large one. When both first claws were removed they invariably regenerated in their original relations.

First, parts of the big chela were removed to determine how great a portion of it was necessary to prevent reversal with regeneration. The large leg was cut off at various levels, but after a day or so the entire leg was thrown off from the breaking-joint when cut at any place more proximal than the base of the most distal segment or the hinge of the pincer. Either part of the pincer itself might be removed, or the entire pincer cut off, without subsequent throwing off of the leg, and in all such cases the pincer was regenerated on the big leg at the next molt, no reversal taking place. A method of slow anæsthesia might be employed by which other operations on the big leg could no doubt be made without causing the leg to be cast off.

Second, it was found in most cases that when both first legs were removed at the breaking-joint and several other legs on the side of the big claw were cut off, the big claw regenerated small and was equal in size to the regenerated little claw. This equality persisted after a second molt in several cases. When either of these legs of equal size is removed the other grows into a large leg and a small leg regenerates from the stump of the removed one.

Third, when the large first leg is removed and several of the legs on the side with the small first leg, then the small first leg does not always grow to be large, but remains small and the first leg of the other side regenerates small; so here again both first legs are of equal size. In two cases several of the removed legs on the little claw side failed to regenerate and in these cases it is important to note that the first small leg grew to be a large one.

Unfortunately the above results do not invariably follow, yet they seem to suggest that a certain amount of reserve growth energy is necessary in order that one of the first pair of legs may grow to form the large claw. Further, this energy seems to be somewhat bilaterally distributed, so that when one side is forced to regenerate several legs it is sometimes rendered incapable of producing the first big claw.

An attempt was made to collect tumor and cancer-like growths from the fishes of this region. A large ovarian tumor was taken from a shark, and a gray snapper, *Lutianus griscus,* was captured which showed a leiomyoma below the eye. These specimens will be studied histologically later.

Experiments in Echinoderm Hybridization, by David H. Tennent, Bryn Mawr College.

During my stay of about two months at the Tortugas Laboratory I continued the investigations on Echinoderm hybridization which I began at the laboratory of the U. S. Bureau of Fisheries at Beaufort in 1907.

H. M. Vernon's paper (1898) on "The relations between the hybrid and parent forms of echinoid larvæ" brought out the interesting fact that there was a seasonal variation in echinoid hybrids. He suggested that the occurrence of "maternal" hybrids in the summer and of "paternal" hybrids in the winter was due to the relative ripeness of the sexual products used in the crosses.

Leonard Doncaster (1904), in his paper entitled "Experiments on hybridization, with special reference to the effect of conditions on dominance," concluded that temperature is the chief if not the only cause of the seasonal changes observed by Vernon, while Herbst (1906–07), in a careful series of studies on heredity in echinoderms, showed that temperature is a contributing, although not the only determining, factor. In my own completed investigations the material at my command, which I had obtained perforce during the summer only, had given me no opportunity for study along this line.

It was therefore with much interest that I observed that the plutei resulting from a fertilization of the eggs of *Toxopneustes variegatus* by the sperm of *Hipponoë esculenta* were, in a large proportion, paternal in character. A second surprise came when, on attempting the reciprocal cross, *Hipponoë* female by *Toxopneustes* male, I found not only that the cross was easily made, but that it gave "maternal" hybrids. I had, then, a clear case of dominance of one species over another (using the term "dominance" in the sense in which it is applied by Doncaster in distinguishing between prepotency and dominance when referring to individual characters taken separately). That is, a dominance of *Hipponoë* over *Toxopneustes.*

It will be seen at once that the importance of seasonal change in the hybrids, whether dependent on temperature or not, had been appreciably lessened. My problem, therefore, was the determination of the unknown factor, the undetermined factor of Herbst's earlier papers on the subject.

I had been informed that the sea-water in the Tortugas region gave a decided alkaline reaction. Acting upon this information, I tried the effect of increasing and of reducing the alkalinity of the sea-water and found that in this lay the means of controlling the appearance of maternal or of paternal plutei.

The skeleton of the plutei was taken as the basis of comparison between hybrid and parent forms, because my work in previous years had shown it to be the least variable character in pure embryos. My observations were principally made upon the form of the anal-arm skeleton, since it is in this particular that the plutei of the two forms mentioned differ most noticeably from each other.

In *Toxopneustes* the skeleton of the anal arms consists of a single straight rod with numerous thorn-like protuberances or "prickles." In *Hipponoë* the skeleton of these arms is composed of three rods, connected by cross-bars, to form a ladder-like or latticed structure. In these respects the forms in consideration correspond respectively to the plutei of *Strongylocentrotus lividus* and *Sphærechinus granularis,* upon which the greater part of the work done by the European investigators has been based.

In my study of the hybrids I have taken the presence of latticed skeletons as an indication of *Hipponoë* dominance and the occurrence of more than one rod in the anal arms, a most infrequent variation in pure *Toxopneustes* plutei, as an indication of *Hipponoë* influence.

The results of the investigation are most readily given in tabular form. A few words of explanation suffice to make the meaning of the headings of the columns clear.

"Plutei with lattice structure" are plutei which have parallel rods, connected by crossbars, in one or both anal arms.

"Anal-arm rods with lattice structure" designates the total number of anal arms of the plutei considered in the preceding column, which have a skeleton composed of parallel rods connected by crossbars.

"Arms more than one rod" indicates an anal-arm skeleton of more than one straight rod.

"Perfect Hipponoë rods" are anal-arm rods which are as perfect as those found in purely bred *Hipponoë* plutei.

"Perfect Toxopneustes rods" indicates a single straight rod with prickles.

"Perfect Toxopneustes plutei" are plutei of the normal *Toxopneustes* type.

"Perfect Hipponoë plutei" are plutei of the normal *Hipponoë* type.

Summary of Results of Cross-Fertilization.

	Plutei with lattice structure.	Anal arm-rods with lattice structure.	Arms more than one rod.	Perfect Hipponoë rods.	Perfect Toxopneustes rods.	Perfect Toxopneustes plutei.	Perfect Hipponoë plutei.
In ordinary sea-water.							
(Number of plutei studied, 50; temperature of water, 28.5° C.)							
Hipponoë ♂ × Toxopneustes ♀	33	60	39	14	1	0	5
Toxopneustes ♂ × Hipponoë ♀	37	58	40	30	2	0	12
In sea-water of increased alkalinity.							
(400 c. cm. sea-water + 10 drops N/10 NaOH; number of plutei studied, 50; temperature of water, 29° C.)							
Hipponoë ♂ × Toxopneustes ♀	39	57	40	15	2	0	3
Toxopneustes ♂ × Hipponoë ♀	40	62	38	31	0	0	10
In sea-water of decreased alkalinity.							
(400 c. cm. sea-water + 20 drops N/10 acetic acid; number of plutei studied, 50; temperature of water, 29° C.)							
Hipponoë ♂ × Toxopneustes ♀	7	7	62	1	31	7	0
Toxopneustes ♂ × Hipponoë ♀	12	23	68	4	9	3	1
(400 c. cm. sea-water + 10 drops N/10 hydrochloric acid.)							
Hipponoë ♂ × Toxopneustes ♀	5	8	56	4	40	10	0

Comparison of Results of Cross-Fertilization in Normal Sea-Water with Results of Cross-Fertilization in Sea-Water of Reduced Alkalinity.

Hipponoë ♂ × Toxopneustes ♀:							
Sea-water	33	60	39	14	1	0	5
Sea-water + acetic acid	7	7	62	1	31	7	0
Toxopneustes ♂ × Hipponoë ♀:							
Sea-water	37	58	40	30	2	0	12
Sea-water + acetic acid	12	23	68	4	9	3	1

These tables may be summarized in equational form:

(1) Normal sea water:

$$\frac{\text{Hipponoë } ♂}{\text{Toxopneustes } ♀} = \text{Dominant Hipponoë.}$$

$$\frac{\text{Toxopneustes } ♂}{\text{Hipponoë } ♀} = \text{Dominant Hipponoë.}$$

(2) Sea water + NaOH (increased alkalinity):

$$\frac{\text{Hipponoë } ♂}{\text{Toxopneustes } ♀} = \text{Dominant Hipponoë.}$$

$$\frac{\text{Toxopneustes } ♂}{\text{Hipponoë } ♀} = \text{Dominant Hipponoë.}$$

(3) Sea water + acetic or hydrochloric acid (decreased alkalinity):

$$\frac{\text{Hipponoë } ♂}{\text{Toxopneustes } ♀} = \text{Dominant Toxopneustes.}$$

$$\frac{\text{Toxopneustes } ♂}{\text{Hipponoë } ♀} = \text{Dominant Toxopneustes.}$$

The dominance asserted is not complete. The tendency toward dominance is well shown and it is this tendency which may be directed in the manner described.

I believe that in these results we have an explanation of the seasonal variations described by Vernon. The changes in the sea-water in the direction of a decrease in alkalinity which I produced artificially, that is, the reduction in concentration of OH ions, probably corresponding to normal variations which are correlated with changes of season. Connected with this is the idea of specific reaction to different concentrations of OH ions, the optimum for *Hipponoë* lying in a higher, and the optimum for *Toxopneustes* in a lower concentration.

Other crosses made were:

Hipponoë ♀ × Cidaris ♂.
Hipponoë ♀ × Ophiocoma ♂.
Hipponoë ♀ × Pentaceros ♂.
Toxopneustes ♀ × Echinaster ♂.
Toxopneustes ♀ × Holothuria floridana ♂.

None of these crosses were especially successful, the development not going beyond the segmentation stages.

For the *Hipponoë* × *Toxopneustes* crosses material for a cytological research was collected. I also collected material for work on the anatomy of *Pentaceros*.

The Annelid Fauna of Tortugas, by Aaron L. Treadwell, of Vassar College.

My objects in going to the Tortugas Laboratory were (1) to collect as extensive a series as possible of the Polychæta of the region, and (2) to continue observations begun elsewhere on the embryology of this group.

While extensive collections of Polychæta have been made in the West Indian region, these have been mostly of the deeper-water forms, very little being known of the annelids of the shallower waters. There are no mud-flats at the Tortugas, the nearest approach to one being the bottom of the moat at Fort Jefferson. There a few burrowing forms occur, but elsewhere annelids are found only in crevices of the coral rock, where a very large number are to be found in the dead rock, and even, as in the case of some of the Sabellidæ growing through the living coral, the brilliantly colored gills of the annelid protruding from the surface of the rock by the side of the coral polyps. Approximately 50 genera were collected, the largest number of genera being representatives of the Eunicidæ.

Observations were made on the embryology of *Spirobranchus tricornis*, *Pomatostegus stellatus*, and *Eunice fucata* (palolo). The egg of *Spirobranchus tricornis* shows a uniform orange color, due to pigment granules scattered throughout the protoplasm of the egg. This pigment may be collected at one pole of the egg by centrifuging, but apparently is not definitely localized in the normal cleavage. Cleavage is equal, and gives rise to a trochophore much like that of *Polygordius*. Attempts to carry this through the metamorphosis were unsuccessful.

The egg of *Pomatostegus stellatus* has little or no pigment, and cleavage is unequal. The trochophore is opaque, and rapidly metamorphoses into the metameric condition, showing three sets of setæ at the forty-second hour. By the forty-eighth hour of development they settle to the bottom and begin to form a calcareous tube. In 16 days these tubes had reached a length of 3 mm. A number of these have been collected on glass plates and tiles and planted on the coral reef near the laboratory, where it will be possible to determine their rate of growth under perfectly normal conditions.

A few attempts were made at hybridizing these two forms. While the results thus far obtained are too indefinite to be of much value, they indicate that this hybridization will be possible. It is expected that researches along this line will be continued in a subsequent season.

The palolo swarmed on the mornings of July 6 and 7, the last quarter of the moon falling on the night of the 9th–10th. One specimen put in a dark car on the 5th swarmed the morning of the 6th, indicating that withdrawal of light for one night is not sufficient to inhibit the swarming. The egg shows a well-defined ring of bright-green pigment around the animal pole and a patch of pink granules at the vegetal pole, this arrangement of pigment being as marked in the immature as in the mature egg. The green pigment passes entirely into the cross and rosette cells, which in later cleavages are prominent because of this contained pigment. The trochophore has a very broad prototrochal band (covering more than three-fourths of the surface), a very poorly-developed apical tuft, and a narrow paratroch.

Geology of the Keys, the Marine Bottom Deposits, and Recent Corals of Southern Florida, by T. Wayland Vaughan, U. S. Geological Survey.

Boca Grande Key.—Beach ridges of calcareous sand occur on the west, south, and east sides of this key; behind them are mangroves in the swampy areas and bordering the tidal creeks. Over a considerable area of the interior, however, oölite outcrops. This is the most westerly locality from which this rock is at present known.

The Marquesas.—This group forms an atoll, with an interior lagoon, seawardly bounded by an interrupted ridge of calcareous sand rising a few feet above the ocean's level. No hard rock of any kind was observed on them.

The Tortugas.—Sand, Middle, and East keys were examined and found to be composed of calcareous sand. Long Key is mostly made up of wave-tossed stems of *Acropora* and molluscan and echinoid tests. Bush Key, which is covered at high tide, has wave-tossed coral blocks on its summit, and the sea-bottom around it is covered with similar material.

A report on the bottom samples collected during April, 1908, has been prepared for publication and will appear in the next volume of reports from the Tortugas Marine Biological Laboratory.

STUDIES ON MADREPORARIA.

SURVEY OF THE CORAL FIELDS.

Additional observations were made on the local conditions under which the various species of corals occurring around the Tortugas live, and the mapping of the fauna with reference to all ascertainable factors was continued. As yet the various collections have not been critically studied in the laboratory, but in the field it is shown that each species occurs under a more or less definite set of conditions, and in the Tortugas area there are three or four coral faunal complexes, the species of one complex only slightly overlapping those of another. The careful survey of the region is not complete.

Annual surveys of the piers of the Fort Jefferson dock.—Numerous species of corals grow on the piers of the Fort Jefferson dock, which faces the deep channel on the east side of Garden Key. The maximum depth of this channel is 6 fathoms and the tidal currents flow gently through it. The species of corals vary with reference to the position of the piers, and it was thought careful records of the species growing on each pier would give results showing the influence of several factors in determining the habitat of the respective species. These surveys also afford material for growth observations. They were begun in 1908, and continued in 1909.

Annual surveys of the Fort Jefferson moat.—The sea has access to the moat surrounding Fort Jefferson, and a number of species of corals grow in it. The movement of the water in it is sluggish, and during periods of heavy rain its degree of salinity is less than that of the ocean. The general vital conditions prevalent in the moat simulate those of a flat inside a key except it is subject to greater variation in the degree of salinity of the water and because of deficient circulation the water may become more highly heated by the sun. The corals are not uniformly distributed in the moat. Therefore in 1908 a detailed survey of it was made to determine the distribution of each species living in it and to see if factors determining the habitat could be discovered. Numerous growth observations are being conducted on the species living there. Transplanting experiments in it are described subsequently. The surveys are being repeated annually to note any changes.

Considerable information has been procured on the habitat of the corals inhabiting the moat, but it is not in condition for presentation. One growth-record is interesting. In 1908 no specimen of *Oculina* growing naturally in the moat was observed; but in 1909 two rather large colonies were discovered in a conspicuous place examined in 1908. If these colonies were there in 1908, they were probably small. They were measured on May 15, and, after my departure from the Tortugas, were again measured by Dr. Mayer on July 13. The amount of growth in millimeters is given below.

Date.	Length and breadth.	Height.	Branches.
		mm.	
A. May 15, 1909..	Basal expansion 105 mm. across.	35	1, bifurcated at summit (a single branch).
A. July 13, 1909..	.....	* 41	
B. May 15, 1909..	Basal expansion 80 mm. across.	35	4 single, 2 bifurcated at summit; 2 clusters, 1 composed of 6 branches, the other of 5, 1 bifurcated at summit.
B. July 13, 1909..	83 mm.....	35 to 50	13 single and 2 bifurcated branches.

* Excepting the increase in height the same as on May 15.

Rate of Growth.

In 1908 a series of measurements was initiated to determine the rate of growth of corals, and the results at the end of the first year are given in the

Table showing Rate of Growth.

	Length.	Breadth.	Height or thickness.	Remarks.
	mm.	*mm.*	*mm.*	
Eusmilia knorri, Pier V, 12:				
A. May 8, 1908.....	.....	.....	.....	2 calices, 1 dividing into 3 calices.
A. May 18, 1909.....	51	34	27	8 separate calices.
B. May 8, 1908.....	.....	.....	.....	6 calices, branches all short.
B. May 18, 1909.....	.....	.....	About 30	11 or 12 calices, forming 6 branches.
Oculina sp. (diffusa?):				
Pier V, 7—				
B. May 8, 1908.....	.....	.....	[1] 12 to 25	Colonies basal incrustations with numerous branches.
B. May 18, 1909.....	112	112	[2] 40	
C. May 8, 1908.....	.....	.....	[1] 12 to 25	
C. May 18, 1909.....	112	112	[2] 45	
Pier V, 8—				
B. May 8, 1908.....	[3] 125	[3] 125	75	
B. May 18, 1909.....	180	180	75	
Manicina gyrosa, Pier V, 8:				
May 8, 1908.....	ca 125	ca 125	.....	
May 18, 1909.....	154	154	.....	
Agaricia agaricites var., Pier VI, 1:				The colony a thin, closely incrustating plate.
May 8, 1908.....	50	37	.....	
May 18, 1909.....	69	54	.....	
Porites furcata, Pier I, 5:				
A. May 10, 1908.....	.....	.....	25	1 nodule, 25 mm. tall.
A. May 8, 1909.....	110	70	40	6 protuberances, tallest 40 mm. high, bifurcated, with a branch 15 mm. tall; 3 other protuberances trifurcated; 2 simple nodules.

[1] Range of branches. [2] Tallest branch. [3] Diameter of cluster.

table. The number of observations is small, and while the measurements were not so complete or accurate as desired, they are important as showing the growth to be rather rapid. During the past field season (May, 1909) the number of growth observations was extended, so that now records are kept of the growth rate of 53 separate colonies, representing 13 species. The planted attached young, to which reference will later be made, are not included in this number. The measurements for 1909 are more complete and more accurate than those for 1908, but still greater accuracy is desired and will be obtained. It is also intended to increase the observations until rather large series of all the shallow species are included. All of the colonies for which measurements are given live on the piers of the Fort Jefferson dock.

Transplanting Experiments.

In 1908 two specimens of *Mæandra clivosa* were transplanted from the strong light of the outside of the piers to the shaded area under the warehouse. One of the specimens was broken from its attachment, while the other held. The latter died, but that the change of habitat was responsible for its death is not positive, as the specimen may have been exposed at low tide.

Specimens of *Eusmilia knorri, Oculina* sp., *Favia fragum, Mæandra labyrinthiformis, M. areolata, M. clivosa,* and *Porites porites* var. were transplanted from the piers of the Government dock to the fort moat. The fate of the specimens (*Eusmilia, Oculina, Favia fragum, Mæandra arcolata,* and *M. labyrinthiformis*) placed near the western entrance to the moat is given in a letter from Dr. Mayer dated May 27, 1908:

> We had a very low spring tide in the moat and this fully exposed your corals near the entrance. The *Oculina,* such portions of the *Eusmilia* as were exposed, and the *Mæandra labyrinthiformis* were killed. The *Porites, M. areolata,* and *Siderastrea* were not apparently injured by the exposure.

Because of insecure attachment, all of the specimens placed in this locality were washed away. Specimens of *Favia fragum* and one of *Mæandra areolata* placed near the sallyport of the fort were also washed away. A species of *Orbicella annularis* was transplanted from the reef near the fort to the moat. Part of it was killed by exposure at low tide and subsequently it all died. It apparently could not stand the moat conditions. Specimens of the following species lived: *Eusmilia knorri, Mæandra areolata, M. labyrinthiformis,* and *M. clivosa.* Unfortunately all were not measured in 1908 for growth rate.

	Length across calicular surface.	Breadth.	Height.	Total No. of calices.	No. of live calices.
	mm.	*mm.*	*mm.*		
Eusmilia knorri:[1]					
May 10, 1908	90	.....	90	.....	12
May 11, 1909	94	66	91.5	15	12
Mæandra labyrinthiformis:[2]					
May 10, 1908	65	65	20	.....	.....
May 11, 1909	85	85	33	.....	.....

[1] This specimen was alive after one year and had grown a little, but was not thriving. It was largely covered with calcareous ooze.
[2] This colony had evidently grown well under the changed environment.

All of the transplanted colonies still alive were fastened to the shelf of the moat wall with hydraulic cement, to prevent their washing away, and growth observations are now being made on all of them.

Notes on the general vital conditions of the moat are given under "Annual surveys of the Fort Jefferson moat."

The transplanting experiments to the moat and the records of corals growing naturally in it give qualitative, not quantitative, results, but they show that certain corals can stand considerable ranges in the temperature of the water and variation in the degree of salinity.

Rearing Corals from the Young.

The live-car in which the young of *Favia fragum* attached to the bottom of a glass dish were placed in July, 1908, was unfortunately broken from its mooring by a storm during the winter and that experiment was terminated. The experiments made in May, 1908, clearly showed the feasibility of having the planulæ of corals attach themselves in the laboratory, and planting them in desirable localities. It was decided to use as collectors circular tiles, 8 inches in diameter and 1 inch thick, perforated in the center by a square hole, which fits over the head of an iron stake. An iron stake can be driven into the reef or any other selected place, a tile fitted over its head and made fast by a key and wedges. After a number of planulæ have been extruded from a colony, they are pipetted off and placed in a vessel containing a tile on its bottom. Although a good many planulæ settled on the tiles, many had a persistent tendency to seek the bottom of the vessels outside the periphery of the tile or through its central perforation. In order to preserve these specimens the glass vessels were broken and the pieces bearing the young corals were attached with hydraulic cement to tiles.

Nine tiles, having on them the young of *Agaricia* and 2 species of *Porites*, were planted on a reef off Loggerhead Light. The parent colonies were preserved for comparison with their offspring. After I left the Tortugas, Dr. Mayer cemented 3 additional tiles bearing the young of the same species to the shelf of the Fort Jefferson moat, near the western entrance. Therefore, 12 tiles bearing attached larvæ were planted.

Duration of the Free-swimming Larval Stage of Corals.

Species.	Planulæ extruded.	Attached.	Duration of free-swimming stage in days.
Agaricia crassa	May 9-10	After May 16	6 to 7 days.
	May 11-13	After May 16	3 to 5 days.
	May 12-13	May 15	2 days.
	May 13-14	May 17	3 days.
	May 11-13	May 22-25	11 days (minimum).
Porites clavaria	May 7-8	May 15-16	7 to 9 days.
	May 8-9	May 14	5 days.
	May 9-10	May 14	4 days.
	May 9-10	May 16	6 to 7 days.
	May 8-9	After May 16	7 to 8 days.
	May 8	May 21 to June 2	13 and 13+ days.
Porites astreoides (?)	May 13-14	May 16	2 to 3 days.
	May 13-14	May 21 to June 2	7 and 7+ days.

In the last Year Book of the Carnegie Institution of Washington (pp. 135, 136) I published that the free-swimming larval stage of *Favia fragum* was,

according to observation, from 5 to 12 days, and that one planula of *Porites astreoides* was free for about 7 days. This year I can add *Agaricia crassa*, 2 to 11 days, and *Porites clavaria*, 4 to 13 days. This duration of the free-swimming larval stage renders possible a very extensive distribution of these organisms by ocean-currents. It is intended to extend the rearing experiments to all species of which young can be procured.

The Planting of Collectors.

Hoping that young corals might be obtained by judiciously planting collectors, series of tiles with no young attached were planted on each of the three reefs off the northwest shore of Loggerhead Key—24 tiles were planted on the northeast reef, 25 on the middle reef, and 12 on the southwest reef. These collectors will be observed from year to year, and it is hoped may furnish material for growth observations and transplanting experiments.

A SUMMARY OF THE RESULTS ACHIEVED BY THE LABORATORY DURING THE FIVE YEARS 1905–1909.

During these first five years of its existence 29 investigators have studied under the auspices of the Laboratory, and among these 10 have paid two or more visits to the station, and thus 44 visitors have come to the Laboratory for the purpose of investigation; 30 papers have been published by these investigators as a result of their studies, and in addition 12 papers have been produced by the Director, bringing the total output of papers up to 42. This enumeration does not include papers presented for publication or now in press, or preliminaries published in the Year Books of the Institution.

The following table will serve to give an idea of the scope of these researches and of their places of publication:

Name of investigator.	Date of visit to laboratory.	Subject of research.	Where published.
Brooks, Wm. K., Johns Hopkins University.	1905, 1906	Salpæ; Appendicularia; Origin of lung of Ampullaria (with B. McGlone).	Papers from Tortugas Laboratory, vol. 1 (4 papers), 1908.
Chapman, Frank M., American Museum of Natural History.	1907	Life histories of booby and frigate-birds nesting on Cay Verde, Bahamas.	Papers from Tortugas Laboratory, vol. 2, 1908.
Cole, Leon J., Yale University.	1906	Habits of ants.	
Conklin, E. G., Princeton University.	1905, 1907	Development and structure of egg of Medusæ; Actinian larvæ.	Papers from Tortugas Laboratory, vol. 2 (2 papers), 1908.
Cowles, R. P., Johns Hopkins University.	1905, 1906, 1908, 1909	Habits and reactions of ghost crab and of star-fishes.	Papers from Tortugas Laboratory, vol. 2, 1908.
Dahlgren, Ulric, Princeton University.	1906	Histology of muscles.....	Histology of muscles of Cassiopea, in "Principles of animal histology," with Wm. A. Kepner.
Edmondson, C. H., Iowa...	1906	Protozoa	Papers from Tortugas Laboratory, vol. 1, 1908.
Hartmeyer, R., of Berlin Zoolog. Museum.	1907	Ascidians; general collecting.	Deutsch Gesell. für volkstumliche Naturkunde, 1908; also, Meereskunde, Jahrg. 3, Heft 2, 40 pp., 1909.

Name of investigator.	Date of visit to laboratory.	Subject of research.	Where published.
Harvey, E. Newton, University of Pennsylvania.	1909	Physiology and chemistry of animal movement; Effects of acetic acid in forming egg-membrane.	
Hooker, Davenport, Yale University.	1905, 1907, 1908	Reactions of newly-hatched sea-turtles.	Paper presented for publication by the Carnegie Institution of Washington.
Jennings, H. S., Johns Hopkins University.	1905	Modifiability in behavior of sea-anemones.	Journal of Experimental Zoology, vol. 2, No. 4, 1905.
Jordan, H. E., University of Virginia.	1907	Cytology; Accessory chromosomes; Echinoderms and Aplopus.	Zool. Anzeiger, Bd. 32, pp. 284-295, 1908; also, Papers from the Tortugas Laboratory, vol. 1 (3 papers), 1908.
Kellner, Carl, Yale University.	1905, 1906, 1907	Embryology of the appendicularian Oikopleura.	Zool. Anzeiger, Bd. 31, May, 1907.
Linton, Edwin, Washington and Jefferson College.	1906, 1907, 1908	Habits of Fierasfer; Helminth fauna of Tortugas.	American Naturalist, vol. 41, pp. 1-4, 2 figs., 1907; also, Papers from Tortugas Laboratory, vol. 1, 1908.
McClendon, J. F., Cornell Medical College.	1908	Reactions and œcology of Synalpheus and Cradactis.	Two papers presented for publication by the Carnegie Institution of Washington.
Meek, Seth E., Field Museum of Natural History, Chicago.	1909	Habitats of coral-reef fishes for the construction of a group in the Field Museum of Chicago.	
Osburn, Raymond C., Columbia University.	1908	Bryozoa.	
Perkins, H. F., University of Vermont.	.....	Medusæ.....	Papers from Tortugas Laboratory, vol. 1, 1908.
Pratt, H. S., Haverford College.	1909	Trematodes and Cestodes.	
Reighard, Jacob, Michigan University.	1905, 1907	Warning coloration and associative memory in fishes; Photography of marine animals in their natural habitats.	Papers from Tortugas Laboratory, vol. 2, 1908; also, Bulletin U. S. Bureau of Fisheries, vol. 27, pp. 41-68, plates, 1908.
Stockard, C. R., Cornell Medical College.	1907, 1908, 1909	Tissue growth and regeneration; Habits, œcology, inheritance, and mating-instinct in the "walking-stick" insect.	Papers from Tortugas Laboratory, vol. 2 (2 papers), 1908; also, Journal Experimental Zoology, vol. 6, pp. 433-469, 1 plate, 1909; also, Biological Bulletin, vol. 17, pp. 239-245, 3 figs., 1909.
Stromsten, Frank A., Iowa University.	1907	Embryology of loggerhead turtles, with special reference to the vascular system.	
Tennent, David H., Bryn Mawr College.	1909	Development of hybrids in Echinoderms, and the effects of environment in the determination of dominance.	
Tower, W. L., Chicago University.	1908, 1909	Effects of enviroument, etc., upon evolution and heredity in beetles.	
Treadwell, Aaron L., Vassar College.	1909	Annelids of the Tortugas.	
Vaughan, T. Wayland, U. S. Geological Survey.	1908, 1909	Geology, œcology, and effects of environmental factors in the growth of corals.	Smithsonian Miscellaneous Collections, vol. 52, pt. 4, No. 1877, pp. 461-464, plates and figs., 1909.
Wallace, W. S., New York City.	1908	Hydroids of Tortugas.	
Watson, John B., Johns Hopkins University.	1907	Breeding habits and reactions of sea-gulls upon Bird Key, Tortugas.	Papers from Tortugas Laboratory, vol. 2, 1908.
Zeleny, Charles, University of Illinois.	1906	Relation between degree of injury and rate of regeneration; Effect of successive injuries upon regeneration.	Papers from Tortugas Laboratory, vol. 2, 1908; also, Journal of Experimental Zoology, December, 1907.

In this review it will be impossible to do full justice to the published papers, owing to limitations of space, and I will confine the presentation of results to include only the more important laws and facts discovered. The studies of Messrs. Brooks, Edmondson, Hartmeyer, Linton, Osburn, Perkins, Pratt, Treadwell, and Wallace have been in systematic zoology and have resulted in the discovery of many new and interesting species, but it will be impossible to review them in this brief report.

Brooks and McGlone find that there is no reason to believe that there is any ancestral connection or relationship between the lung of the prosobranchiate gastropod *Ampullaria* and that of the pulmonates, although the embryonic history of the lung of *Ampullaria* shows that the origin of the lung of the pulmonates through the modification of a gill is not impossible.

Dr. Frank M. Chapman discovered that the booby (*Sula fiber*), which nests upon Cay Verde, Bahamas, between February and April, lays two eggs, but rears only one young bird. His observations and collections upon Cay Verde have led to the construction of a group in the American Museum of Natural History illustrating the nesting-habits of the frigate-bird and the booby.

Prof. Edwin G. Conklin finds that the egg of the scyphomedusa *Linerges* consists of a peripheral layer of clear protoplasm, an intermediate shell of densely-packed yolk-spherules, and a central sphere of dissolved yolk. The peripheral layer of the egg forms the peripheral layer of the gastrula and blastula and gives rise to the cilia of the ectoderm. The middle layer constitutes the principal part of all of the cells of the body, while the central yolk serves for nourishment. Thus animals so low as the medusæ show the beginning of that differentiation of organ-forming substances in the egg which Professor Conklin discovered was so characteristic of the eggs of higher forms.

Dr. R. P. Cowles carried out a very extensive series of observations upon the habits and reactions of the ghost crab (*Ocypoda arenaria*), which lives upon the sandy beaches of the Tortugas. It will be impossible to do more than present a few of his most important results. He finds that this crab can not detect color, but is sensitive to large differences in the intensity of light, and it readily perceives a moving object. The color-pattern of the crab changes under different conditions of light and temperature, becoming dark and mottled in dull light and low temperature. It can not detect sound-waves traveling through air, and its so-called "auditory organs" are actually organs of equilibration. The crab has memory, is able to profit by experience, and can form habits.

Mr. E. Newton Harvey carried out a series of experiments upon the influence of changes of temperature in reducing or accentuating the effects of the cations of the salts of sea-water upon the pulsation of the medusa *Cassiopea*. He concludes that the ions of these salts exert their influence upon pulsation and contraction in a chemical rather than in a mechanical or physical manner. By adding acetic acid to the sea-water he caused the normally fertilized embryo of the sea-urchin to form a double membrane even as late as the blastula stage.

Mr. Davenport Hooker found that the newly-hatched young of the loggerhead turtle (*Thalassochelys caretta*) is attracted toward the ocean by the blue color of the water. If it sees the ocean through red, yellow, or green glass it does not crawl toward it, but if a piece of blue glass, or even blue paper, be placed anywhere within range of its vision the turtle at once crawls toward it with evident excitement.

Prof. H. S. Jennings found that in several sea-anemones the reactions to stimuli are modified as a result of the past experiences of the animal. The reaction to a given stimulus is not a set invariable property of the organism, but depends on the state of internal processes, thus the stimulus of food may in the same individual produce widely diverse reactions, dependent upon the past experiences and present internal state of the animal.

Prof. H. E. Jordan finds that in echinoderms the chromosomes arise inconstantly in different species from any part of the germinal vesicle that contains the chromatin material, and this may be either nucleolus, nuclear reticulum, or both. The germinal spot may serve as a storehouse of material which is to contribute toward the formation of the chromosomes. The chromatin not so employed is reabsorbed by the cytoplasm and may serve as food. This casts doubt upon the theory of the individuality of the chromosomes in inheritance.

In *Asterias forbesii* and *Hipponoë esculenta,* during the latter half of the growth period of the oocyte, all of the chromatin, with the exception of that contained in the chromosomes, becomes stored in the enlarging nucleolus. The chromosomes therefore do not arise out of the nucleolus, but the latter merely contributes nutritive substance to them. The reduced number of chromosomes is 18.

Professor Jordan also finds that in the walking-stick insect *Aplopus* the somatic number of chromosomes for the female is 36, the spermotogonial number 35, and the number for the primary spermatocytes 18. One of these is a large U-shaped chromosome which remains undivided during the primary spermatocyte reduction division, so that finally one half of the spermatozoa contain 18 and the other half only 17 chromosomes. The accessory chromosome is apparently a sex-determinant.

Mr. Carl Kellner finds that a new species of house-making appendicularian (*Oikopleura tortugensis*) bears parasitic embryos, apparently its own, attached to its tail.

Prof. Edwin Linton made an interesting observation upon the habits of the fish *Fierasfer affinis,* which lives commensally within holothurians. The fish inserts the tip of its long pointed tail within the cloacal orifice of the holothurian, and then draws itself backwards into its host.

Dr. J. F. McClendon studied the feeding habits and general reactions of the sea-anemone *Cradactis,* which lives in the crevices of corals and crawls about upon its tentacles. He also discovered an interesting case of parallelism in habits and general appearance between the crustacea *Synalpheus* and an Amphipod, both of which live within the cavities of the loggerhead sponge. His paper has been presented to the Carnegie Institution of Washington for publication.

Prof. Jacob Reighard discovered that the brilliantly colored fish which live among the crevices of coral reefs and which previous observers had assumed were warningly colored, are in fact voraciously eaten by the gray snapper whenever this predaceous fish can capture them. Hence they are not warningly colored, but owe their immunity solely to the protection of the coral caverns. Nevertheless, Professor Reighard found that the gray snapper could distinguish colors, and that it could be taught to associate a definite color with an unpleasant taste; for when the prey is given an artificial warning color and at the same time rendered unpalatable, after a brief experience it is no longer taken as food by the gray snapper. Thus warning coloration may be artifically established, but appears not to exist in nature. In these experiments Professor Reighard dyed red the so-called sardines (*Atherina*) and the gray snappers fed upon these red fish without hesitation. Then, however, the tentacles of a medusa were placed in the mouths of the red-colored sardines and the gray snappers soon learned after a brief experience with the stings to avoid them; and they still avoided red-colored sardines after an interval of 20 days had elapsed since they had last seen them, although these later red fish had no medusa tentacles in their mouths.

Professor Reighard's experiments are by far the most convincing that have ever been carried out upon the subject of warning coloration, being performed in surroundings natural to the animals themselves. He concludes that the conspicuous coloration of coral-reef fishes is without biological significance, and is the result of race tendency unchecked by selection.

Prof. Charles R. Stockard carried out an important series of studies upon the regeneration in the medusa *Cassiopea xamachana.* He finds that regeneration takes place more rapidly from cuts made near the center of the disk than from cut edges near the margin of the bell. A small medusa regener-

ates faster than a large one. Morgan's results in the regeneration of the earthworm, fish, and salamander are substantiated in the medusa, and thus it appears that it is a general law that the deeper the level of the cut the faster the rate of regeneration. The degree of injury has little or no effect upon the rate of regeneration, and it makes no appreciable difference whether the regenerating tissue be pulsating or at rest.

One of the most suggestive of Professor Stockard's results is his discovery that the regenerating tissue grows, if necessary, at the expense of the body itself, and if starved the old body actually decreases in size to provide nutriment for the rapidly proliferating cells of the regenerating tissue. He shows that in its remarkable ability to absorb nutriment regenerating tissue resembles cancer and other malignant tumors. He finds that $CaCl_2$ and NaCl tend to retard regeneration, as do also strong solutions of KCl, but weak solutions of KCl accelerate the process.

Professor Stockard extends his studies on regeneration to include two species of brittle-stars (*Ophiocoma*), and here again he finds that the nearer the cut is made to the margin of the central disk the faster will the arm regenerate, but removing more than one arm does not increase the rate of regeneration. Hence the animal with the greater number of removed parts does *not* regenerate each part at a faster rate than the animal with the lesser number of removed parts.

Another of Professor Stockard's researches was upon the habits of the walking-stick insect *Aplopus,* which lives upon the bay cedar (*Suriana*) bushes at Tortugas and bears a striking resemblance to a stick of the bush itself, while its eggs resemble the seeds of the same bush. Professor Stockard finds that the habits of the insect accord perfectly with and enhance the value of its protective coloration. The insect is active only at night, or in darkness; and in daylight they may be piled one on top of another, remaining motionless in any attitude.

In another research, Professor Stockard studied the regeneration of the chelæ in *Alpheus.* It is well known that if the large chela of *Alpheus* be cut off, the small chela changes into a large one at the next molt. Professor Stockard finds, however, that if the large chela be removed, and at the same time some legs of the opposite side of the body (except the small chela) be cut off, the small chela does not change into a large one and the animal acquires two equally developed small chelæ at the next molt. Thus the tendency toward a reversal is checked. Stockard also checked this tendency in two other ways which are described in his preliminary report, herewith published.

Prof. David H. Tennent has discovered that if the two sea-urchins *Hipponoë* and *Toxopneustes* be reciprocally crossed in natural sea-water or in sea-water rendered decidedly alkaline with NaOH, the *Hipponoë* parent is

dominant in the hybrid larvæ. But if sea-water be treated with acetic acid or HCl, so as to reduce but not destroy its alkalinity to litmus, the *Toxopneustes* parent becomes dominant.

Professor Tennent has thus shown that dominance, or prepotency, may be altered by changes in the environment, and his results are comparable with those of Tower in altering dominance in beetles through changes in temperaature and humidity, or with those of MacDougal in the artificial production of new forms of plants through changes induced by external agents upon the germ-cells. His paper upon this interesting subject is being prepared for publication by the Carnegie Institution of Washington.

Prof. Aaron L. Treadwell has made a study of the swarming habits of the Atlantic palolo-worm *Eunice fucata,* which swims for breeding purposes upon the surface of the sea within three days of the time of the last quarter of the July moon, and he has discovered that if the rocks containing the worms be placed in a dark chamber upon the day preceding the night of the swarm the worms may still swarm. Hence, contrary to Mayer's supposition, the presence of moonlight is not necessary for the swarming reaction. Previous studies at Tortugas have shown that the swarming is not due to tidal influences.

Dr. T. Wayland Vaughan finds that the line of the Florida Keys from Soldier's Key to the southeastern corner of Big Pine Key is composed of elevated coral-reef rock. The northern end of Soldier's Key and all keys to the northward of it are composed of siliceous sands with some comminuted shells. The keys from Boca Grande to Big Pine Key, with the exception of the southeastern corner of the latter, are composed mainly or in part of oölitic rock, which in places shows mud-cracks. On the continental side of the line of the coral-reef keys, extending transversely to their trend, are long shoals formed by deposition of mud in the slack-water between the currents which flow in and out with the tides through the openings between keys. These shoals become covered with mangroves, and thus finally elevated above the surface of the sea. There are many other interesting geological observations made by Dr. Vaughan which limitations of space prevent us from reviewing.

In addition to his studies of the geology of the reefs, Dr. Vaughan is making the most accurate and extensive investigation of the natural associations, habits, rate of growth, and constitution of coral reefs ever attempted by any naturalist. He is rearing corals from the planula, and observing their rate of growth as well as studying the growth-rate of many coral-heads found living upon the reefs or in the moat of Fort Jefferson. Years must elapse before the results of these studies will be ready for publication, but he has already discovered that under favorable conditions the rate of growth of corals is

surprisingly rapid, and that the free-swimming stage of the planula may last long enough for corals to be drifted fully 800 miles by the Gulf Stream. He finds, also, that the peculiar and very characteristic associations of definite species of corals is determined by local conditions, such as the presence or absence of currents, roughness or calm of the water, etc. Certain species can grow only in rough, others only in protected waters, others must have strong currents, and still others weak currents for their development.

Prof. John B. Watson made an elaborate study of the nesting habits of the noddy (*Anous stolidus*) and the sooty terns (*Sterna fuliginosa*), which nest upon Bird Key, Tortugas, from May to August. It will be impossible to do justice in a brief review to his painstaking and interesting work, representing as it does the results of the most thorough and suggestive study of the life-processes in sea-gulls yet attempted. He reared the young birds and found that they could learn their way through a maze to their food. The adults could also learn to overcome obstacles in seeking to sit upon the egg. The noddy builds its nest in bushes, and while so doing is quite shy, but if an egg be placed in the nest it loses all shyness and sits upon the egg as if it were its own. Both male and female build the nest, but the male alone procures food for both during this period, the female constantly guarding the nest. After the egg is laid both male and female fly away to fish and take their turns in brooding the egg at intervals of about 2 hours. The egg hatches after 32 to 35 days of incubation. The noddy does not recognize its own egg, but will readily incubate the egg of the sooty or any object, colored or uncolored, bearing more or less resemblance to an egg. It recognizes the locality of its nest and returns to the old locality if the nest be moved, but it will accept an artificial nest placed in the old nest locality without hesitation. Dyeing one of the mates in strange colors caused the undyed bird to attack it, and indeed all other birds upon the island displayed excitement at the appearance of a dyed bird.

The sooty tern nests upon the ground and recognizes the exact locality of its nest; if, however, the nest be raised vertically, the bird readily alights upon it; then if after an interval it be lowered the bird attempts to alight in the air above the nest in the place where the nest was formerly. A slight horizontal movement of the nest causes great confusion in the bird.

Professor Watson caused adult birds to be taken from Bird Key to Havana, 80 miles, to Key West, 66 miles, and to Cape Hatteras, 850 miles from Bird Key. Birds liberated at these places returned in a very short time to their nests on Bird Key. The sooty terns returned from Cape Hatteras in 5 days, and as they probably flew along shore and not by the straight-line route, they must have flown at least 1,081 miles. This is a most striking experiment, for Cape Hatteras is far to the northward of the northern limit of the geographical range of these birds.

Prof. Charles Zeleny studied the regeneration of the chelæ of the gulf-weed crab (*Portunus sayi*) and found that there is no change in the power of regeneration as a result of successive removal of the chelæ, and also that there is no appreciable change in the left chela as a result of the removal and regeneration of the right chela. He also studied regeneration in the medusa *Cassiopea* and discovered that the rate of regeneration is independent of the functional activity or inactivity of the medusa. This result was substantiated by the later work of Stockard. In some other respects Stockard's conclusions are in conflict with those of Zeleny, although their observations are essentially in accord one with another.

Among other researches carried out at Tortugas mention may be made of the work of the Director, who finds that in sea-water the sodium ion stimulates, while mangesium, calcium, and potassium tend to retard neuro-muscular activity in marine animals. The sea-water is thus a balanced fluid, the stimulating influence of the Na being offset by the inhibiting effect of Mg, Ca, and K. Pulsations or other muscular movements of marine animals are thus due to internal stimuli. In the case of the scyphomedusæ the stimulus which produces pulsation is due to the constant formation of $Na_2C_2O_4$ in the sense-clubs, and this precipitates the Ca of the $CaCl_2$ of the sea-water forming the CaC_2O_4 crystals of the sense-club and setting free NaCl, which acts as a nervous and muscular stimulant; and indeed sodium may be the natural stimulant for the production of movements in all marine animals.

The Director also discovered that the cilia of marine animals are affected by the cations of the sea-water in a manner the exact converse of the muscles. Thus sodium is the most powerful stimulant for nerves and muscles, but the most potent inhibitor of ciliary movement. Also magnesium is the most powerful inhibitor in the sea-water for the neuro-muscular system, but the most active stimulant for cilia. Similarly, weak solutions of potassium at first stimulate, later retard the neuro-muscular system, but they first retard and later stimulate cilia. Strong solutions of potassium at once inhibit muscles but temporarily stimulate cilia. Calcium weakly inhibits muscles and stimulates cilia.

Thus for the neuro-muscular system, we have the stimulating effect of Na offset by the stupefying influence of Mg, K, and Ca; whereas upon animal cilia the stupefying influence of Na is offset by the stimulating influence of Mg, K, and Ca.

Moreover, certain bacteria living in fresh-water react to these ions as do the cilia of animals, and this inclines one to suppose that the ciliary movement of animals may have been taken over directly from plant-like ancestors, and that neuro-muscular movements were developed later, and in a converse manner.

As a practical result it is found that a ⅜-molecular solution of $MgCl_2$ or $MgSO_4$ is a valuable fluid for stupefying marine animals, enabling one to kill them after treatment in the magnesium in a completely uncontracted state. There is, however, such great diversity in the reactions of motile plants to these ions that the above hypothesis must be advanced with caution, merely as a possibility.

Another result is that if a contraction wave be once *started* in any *one direction* in a ring-shaped strip of any tissue capable of pulsation, the wave will continue traveling around and around the circuit until interfered with and annulled by a wave coming in the opposite direction. This applies to the vertebrate heart as well as to the medusa, and the experiment enables us to study the phenomena of transmission independent of recurrent stimulation.

In conclusion, we may say that the success of the efforts of those who have come to study at the Tortugas appears to justify the policy which the Laboratory has pursued in choosing certain gifted men for its guests each season, rather than throwing open its doors to general applicants. In our enlightened land those whose studies lead to the discovery of laws of nature do not long remain unappreciated and unknown, but our national effort is happily directed to discover such as soon as possible among the rising generation.

A very large proportion of young men of promise have been invited to study at Tortugas in the confident hope that the encouragement which it is the Laboratory's privilege to accord them will result in the advancement of science. And thus at the conclusion of these first five years of its history it is my happy privilege heartily to thank those who have been my companions, for the honor they have done the Laboratory through their achievements in science, and for the courage and devotion which they have displayed in the prosecution of their work. To the crew of the *Physalia,* who have cheerfully stood by their posts in times of danger and hardship and unfailingly performed their duties, I wish to express my appreciation of their fidelity and courage.

DEPARTMENT OF MERIDIAN ASTROMETRY.*

LEWIS BOSS, DIRECTOR.

To the annual report of this Department for 1907-8 (Year Book for 1908, p. 143) is appended an account of its first expedition (August to November, 1908) for the purpose of establishing a branch observatory for meridian observations in San Luis, Argentina. This account includes the essential facts in relation to the new observatory down to November 30 of that year.

Professor Tucker, aided by Mr. Varnum, had remained in San Luis to attend to the construction of the piers and buildings required for the observatory establishment, while I returned to Albany in order to make needed investigations upon the meridian-circle, to ascertain its exact state prior to its dismounting for transportation to San Luis. This, together with the work of dismounting the meridian-circle and preparing it for its long journey, occupied much of my time from November 20 to January 20, 1909. On the latter date I sailed from New York, bound for Buenos Aires, accompanied by Assistants Roy, Zimmer, and Sanford and Recorders Fair and Delavan. In addition to the meridian-circle and subsidiary apparatus, we had with us a photometer for the determination of the brightness of stars in our observing list that had not previously been investigated for magnitude by accurate photometric methods. The stars requiring measurements by us are mostly below the magnitude 6.5^{M}. This photometer is arranged to be used with an absorbing slide for purely differential observations. The telescope is of 4 inches aperture; it is very accurately and solidly mounted with equatorial movement, and is provided with good circles and other accessories for convenient use.

We arrived in Buenos Aires February 13, and the members of the staff were soon sent to San Luis. On the 23d the instruments were dispatched in a special car, and they were delivered at the observatory, which was then fully prepared to receive them, on March 1. The interval between that date and April 4 was occupied in mounting, adjusting, and investigating the meridian-circle, together with setting up clocks, chronographs, photometer, and other apparatus. Adjustment and test observations with the meridian-circle were made on several nights during the progress of mounting the instrument.

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*Address, Dudley Observatory, Albany, New York. Grant No. 542. $20,000 for study of motion and structure of the stellar system of the northern and southern hemispheres. (For previous reports see Year Books Nos. 2, 3, 4, 5, 6, and 7.)

A.—Southern Observatory from Northwest, San Luis, Argentine Republic.

B.—Transit Circle and Photometer Houses, Northeast View, Southern Observatory, San Luis, Argentine Republic.

The difficulties in mounting and adjustment of the Olcott meridian-circle were rather unusual. The wye-plates are fastened upon large brass rings set into large holes in the pier. The microscopes are supported within similar holes in the pier and accurately perpendicular to the divided circles. It was necessary that these ten holes should be molded into the pier very exactly and the 18 rings for the support of the telescope and the microscopes had to be fastened into the piers with still greater precision. The work required to fulfill these conditions was quickly accomplished by the members of the staff without other skilled assistance.

On April 6 the instrument was ready for use in regular observations. Series No. 1 is of date April 6. Between that date and July 26, according to the latest report, 17,291 observations were made in 136 series, upon 86 nights. This was at the weekly rate of 1,080 observations. Taking out 15 Sunday nights, there were 10 wholly cloudy nights. This proves to have been more than the average number for the season. At this rate the annual output of observations would be 56,000 per year; but the period over which these observations extend should be the most favorable of the year. The rate of observation is about four times the yearly average rate attained at Albany at periods of greatest activity. The observers have usually worked in two shifts, one for the day and the first half of the evening, and the other for the last half of the night. The necessity of providing the numerous stellar observations required to ascertain certain systematic errors, always peculiar to observers and instruments, has, however, been somewhat neglected, and adequate attention to such requirements in the future must cut down materially the present rate of observation.

So far as can now be judged from the records of measurements upon the Mire and Nadir, the collimation, level, and azimuth of the instrument have remained fairly constant, so that there is very slight ground for ascribing any serious instability in the piers or to suppose that the "seasoning" of the large piers was insufficient when the observations began.

The full success of the second expedition rested very largely on the outcome of our efforts to transfer the meridian-circle from its piers in Albany to the duplicate piers in San Luis, without the smallest strain or deformation of its parts; so that it should be found in its new site, humanly speaking, identical in all respects to that which it was while last in use at Albany. The smallest shock, or accident, or any default in remounting it, might easily defeat this object. It seems worth while to introduce a brief summary of the observations and tests by which we are convinced that our attempts have been successful.

As stated at the outset, during the period between the first and second expeditions, November 15 to January 20, we had carefully determined the flexure of the instrument. This substantially confirmed previous results.

In November, 1908, we determined the errors of the surface of revolution of the instrument from the meridian plane, due to slight errors of the pivots. Three years previously we had determined the correction on account of minute errors of graduation for every 10′ of the circles with most painstaking care and with what is believed to have been very great precision.

We now repeated these researches at San Luis. The investigation of the corrections due to slight errors in the forms of the pivots first received attention. The result agreed remarkably with the results previously obtained in Albany. The probable error of the differences in the two determinations, Albany and San Luis, respectively, at each point (points 15° apart) was:

Component.	Probable difference.	Probable error of final results.
	″	″
Vertical component...	± 0.07	— 0.04
Horizontal component.	± 0.09	— 0.05

Extreme accuracy is required in order to obtain probable errors of the differences between two determinations as small as the foregoing, even when there is no disturbance of the instrument between the two series. When dismounting, transportation over 76° of latitude (with three transhipments), and remounting intervene, it was very refreshing to find that the pivots, protected as they were with extraordinary care in packing, received no injury whatever. Moreover, the largest error found was only 0.02^s, a quantity which is sometimes neglected in the correction of instrumental results for this class of errors. Yet this error is about 8 times the probable error of determination and is thus essentially real. In linear measurement the largest observed relative displacement of the pivots due to inequalities of the pivots was not more than one sixteen-thousandth of an inch (0.00006). The pivots are slightly elliptical. The fact that this small ellipticity could be detected is confirmatory of the accuracy of the observations themselves.

The determination of horizontal flexure was next investigated. The difference of the two determinations—one at Albany in November, 1908, and the other in San Luis in March, 1909—was 0.13″. This extremely small quantity includes the result of any slight defect in putting the instrument together, so that its parts will be under the same relative strains as at Albany. It also includes the inherent uncertainties in the two determinations themselves, which are always difficult. Discordances much larger than the difference between our two determinations have been developed in successive determinations of this quantity when the instrument has remained unaltered during the interval between determinations. It is quite evident that the mean

of our two determinations is not liable to any error which can exert an appreciably injurious effect upon observations of the stars.

It was indispensable that we should actually determine whether the circles had received any injury during the transfer. Accordingly we made determination of the graduation-correction of points 15° apart, as carefully as could be effected within ten days. The result might show whether the circles had received a severe shock at any time sufficient to deform them at any point. The following comparison of results at Albany and San Luis, respectively, indicate that the circles arrived absolutely intact:

Determinations of Graduation-corrections.

Circle reading.	Corrections of circle A.		Corrections of circle B.	
	Albany.	San Luis.	Albany.	San Luis.
	″	″	″	″
15	—0.11	—0.08	—0.91	—0.96
30	—0.22	—0.28	—0.09	—0.01
45	—0.23	—0.25	0.00	—0.04
60	—0.65	—0.56	—0.55	—0.50
75	—0.08	—0.06	—0.11	—0.11

The mean difference of these two determinations, point by point, is —0.046″, which immediately settles the main question. There is no evidence whatever of a sensible deformation, since the largest difference (assuming the whole of it to be due to a real difference, and not merely to error of observation, as it well might be) is exactly the hundred-thousandth part of an inch. The determination at San Luis, designed merely as a test, is far less elaborate than the original observations at Albany to compute general tables of graduation corrections. Allowing for this, we may assume from the preceding evidence that the probable error of determination of each of these points at Albany is ± 0.02″ and at San Luis ± 0.03″. It is unlikely that either probable error is really so small. Owing to the small number of comparisons, the probable error of the differences can not be computed with accuracy. A second trial of equal merit might show larger differences. But it is certain that the table of graduation corrections derived in Albany are applicable equally well to the readings of the instrument in San Luis, and that they are probably of unusual accuracy.

My return to Albany was by way of Europe, where conference was had with various astronomers concerning fundamental observations in prospect under the initiative of the Paris Congress of last April. This is of great interest in connection with our own project for obtaining fundamental observations both at Albany and at San Luis. A part of my attention was devoted to an examination of records of older observations that may prove

of value in our work, so far as opportunity may be offered to execute such researches of special importance.

After my return here I procured additional assistance for the observatory in San Luis, and on the steamer sailing from New York to Buenos Aires on August 20 a reinforcement of 3 recorders was sent to the new observatory. These are Louis Z. Mearns, Merton J. Roy, and Leroy Jenkins. This brings the staff at San Luis up to 10 persons, with a prospective probability of greater results in the department of computations.

The distractions due to the two expeditions have greatly interfered with the progress of computations in Albany. The staff here consists of 2 assistants and 6 computers—a force entirely inadequate to handle the immense mass of computations in prospect. The computations effected during the year consist in continuing the preparation of the provisional positions and ephemerides of 20,000 stars, which are destined to form a part of the large General Catalogue projected here. Other work of considerable extent has been accomplished in this same line. Extensive routine computations in relation to the proper motions of the stars contained in our Preliminary General Catalogue have also been effected. Various other computations, of a routine nature, upon the accumulated Albany observations with the meridian-circle have consumed a large amount of time. Progress can be reported in some important lines of investigation, involving laborious details. These may be treated in later reports, whenever definite results shall have been reached.

In the few months between the date of my previous report and the dismounting of the instrument 3,526 observations were made with the meridian-circle at Albany. This makes a total of 13,947 such observations by Messrs. Roy and Varnum from October 7, 1907, to November 1, 1908—very largely upon fundamental stars. These observations, with others to be made on the return of the meridian-circle to Albany, are a part of the plan of corresponding observations to be made at the two observatories. There is now good reason to anticipate that the proposed method of combination will result in a good degree of success.

The manuscript of the Preliminary General Catalogue was turned over to the President of the Carnegie Institution of Washington in August, 1908 (Year Book for 1908, p. 141). The nature of this work has been sufficiently described in my reports contained in the Year Books for 1906, 1907, and 1908. This manuscript was turned over to the printer in December, 1908. Much has been accomplished in passing proof for the press; but owing to my long absence there have been considerable periods during which no definite progress could be made. The completion of the final proofs and the publication of the Catalogue ought now to proceed without interruption.

SOLAR OBSERVATORY.*

George E. Hale, Director.

The principal results accomplished during the past year may be summarized as follows:

(1) The probable existence of magnetic fields in sun-spots, mentioned in my last report, has been placed beyond doubt through the detection of all the characteristic phenomena of the Zeeman effect.

(2) As the only known way in which such magnetic fields could be produced at the temperature of the sun is by the rapid revolution of electrically charged particles, it thus appears probable that sun-spots are electric vortices.

(3) Photographs made with the spectroheliograph and the circular polarization phenomena of the double lines in spot spectra agree in indicating that the sun-spot vortices generally rotate in opposite directions in the northern and southern hemispheres. This statement applies particularly to the larger spots, but some large spots, as well as many smaller ones, do not conform to this rule.

(4) The areas of the calcium flocculi, as measured on the spectroheliograph plates, give a new index to the solar activity. A curve showing the mean area corresponding to each solar rotation period, when compared by Dr. Bauer with a curve exhibiting the variations in the earth's magnetic intensity, indicates a general relationship between the solar activity and the terrestrial magnetic activity. No quantitative relationship for individual cases can, however, be detected.

(5) Comparative studies of the hydrogen flocculi, made with moderate and high dispersion, have shown their changes in intensity and form in the vortices, their structure as photographed with different lines and with different parts of the same line, and their characteristic phenomena at different levels in the solar atmosphere.

(6) The radial motion of the calcium vapor in the H_2 and H_3 flocculi has been measured in many parts of the sun's disk.

(7) The "flash" spectrum of the lower chromosphere, previously photographed only at total eclipses of the sun, can be photographed in full sunlight on any good day with the 30-foot spectroheliograph of the tower telescope. The wave-lengths of the bright lines thus recorded are, on the average, in close agreement with those of the corresponding dark lines in Rowland's table.

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*Situated on Mount Wilson, California. Grant No. 543. $104,000 for construction, investigations, and maintenance. (For previous reports see Year Books Nos. 3, 4, 5, 6, and 7.)

(8) A continuation of the spectrographic study of the solar rotation indicates that the rotation rate did not vary appreciably between 1906 and 1908. The observations confirm the earlier ones in showing that different lines give different velocities. The calcium line λ 4227 gives a higher rotational velocity and a smaller equatorial acceleration than the general reversing layer. The *Hα* line of hydrogen gives a still higher rotational velocity and a very small equatorial acceleration.

(9) The motion of the reversing layer in the vicinity of sun-spots appears to be seriously influenced by the motion in the vortices.

(10) By a photographic comparison, it has been shown that the light of the Great Nebula in *Andromeda* and of three star-clusters contains a larger proportion of the less refrangible rays than the light of stars of the same spectral type. On account of the great distance of these objects this is probably due to the selective absorption of light in space.

(11) Photographs of nebulæ, made with the 60-inch reflector, bring out details not previously recorded, notably a remarkable spiral structure near the center of the *Andromeda* Nebula.

(12) Photographs of stellar spectra, made with a spectrograph of 18 feet focal length, used in conjunction with the 60-inch reflector, are on a sufficient scale to permit the determination of the pressure in the atmosphere of *Arcturus*.

(13) In the laboratory a close agreement has been found between the separation into components of lines in sun-spot spectra and their resolution in the magnetic field, both as to magnitude and character of the separation. Preston's law, $\frac{\Delta\lambda}{\lambda^2} = \text{const.}$, holds approximately in the case of iron if mean values of $\Delta\lambda$, representing a considerable number of lines, are used. Experiments have been carried out to show to what extent inclination of the lines of force and polarization by the apparatus may explain certain effects observed in spot spectra.

(14) Electric-furnace investigations have provided a classification of spectrum lines on the basis of their readiness of response to temperature excitation. The laboratory evidence as to the lower temperature of sun-spots has been extended and the foundations laid for a general classification of light sources according to temperature.

(15) Spark spectra under pressure have been photographed for comparison with the spectra of the limb and center of the sun.

(16) A study has been made of iron lines which are relatively strengthened by the spark discharge, and a number of lines have been added to this list.

(17) The fluted spectrum of calcium burning in hydrogen has been measured from large-scale photographs, and the correspondence of these flutings with lines in spot-spectra has been worked out in detail.

Various investigations not mentioned in the above summary are referred to in other parts of this report.

Of the events of the year, the completion of the proof that a magnetic field exists in sun-spots, the remarkably successful performance of the 60-inch reflector, and the evidence obtained with its aid of the selective absorption of light in space call for special mention. Dr. Fath's observations of the spectra of nebulæ and clusters, made last year at the Lick Observatory, indicate that no sharp dividing line can be drawn between the two classes of objects. The Great Nebula in *Andromeda* gives a distinct solar spectrum, and, as it is known to be enormously distant, it may possibly consist of a countless swarm of solar stars, so closely crowded together that they can not separately be distinguished with any telescope. Resolvable clusters, even of the open type, are very remote from the earth. The demonstration by Professor Kapteyn and Mr. Babcock that the *Andromeda* Nebula, as compared with a solar star, is about 1 magnitude brighter when photographed through a red screen than when photographed without a screen is of the greatest importance. Professor Kapteyn's previous investigation of about 1,400 stars seems to prove that violet light is more absorbed than red light in its transmission through space. The absorption coefficient is very small, however, and the impossibility of including faint stars in the investigation made its quantitative determination extremely difficult. The results obtained with the *Andromeda* Nebula and with three star-clusters are of an entirely different order of magnitude. They even suggest the possibility of using this method to measure the relative distances of remote objects, whose parallax and proper motion are too small to be detected.

STAFF.

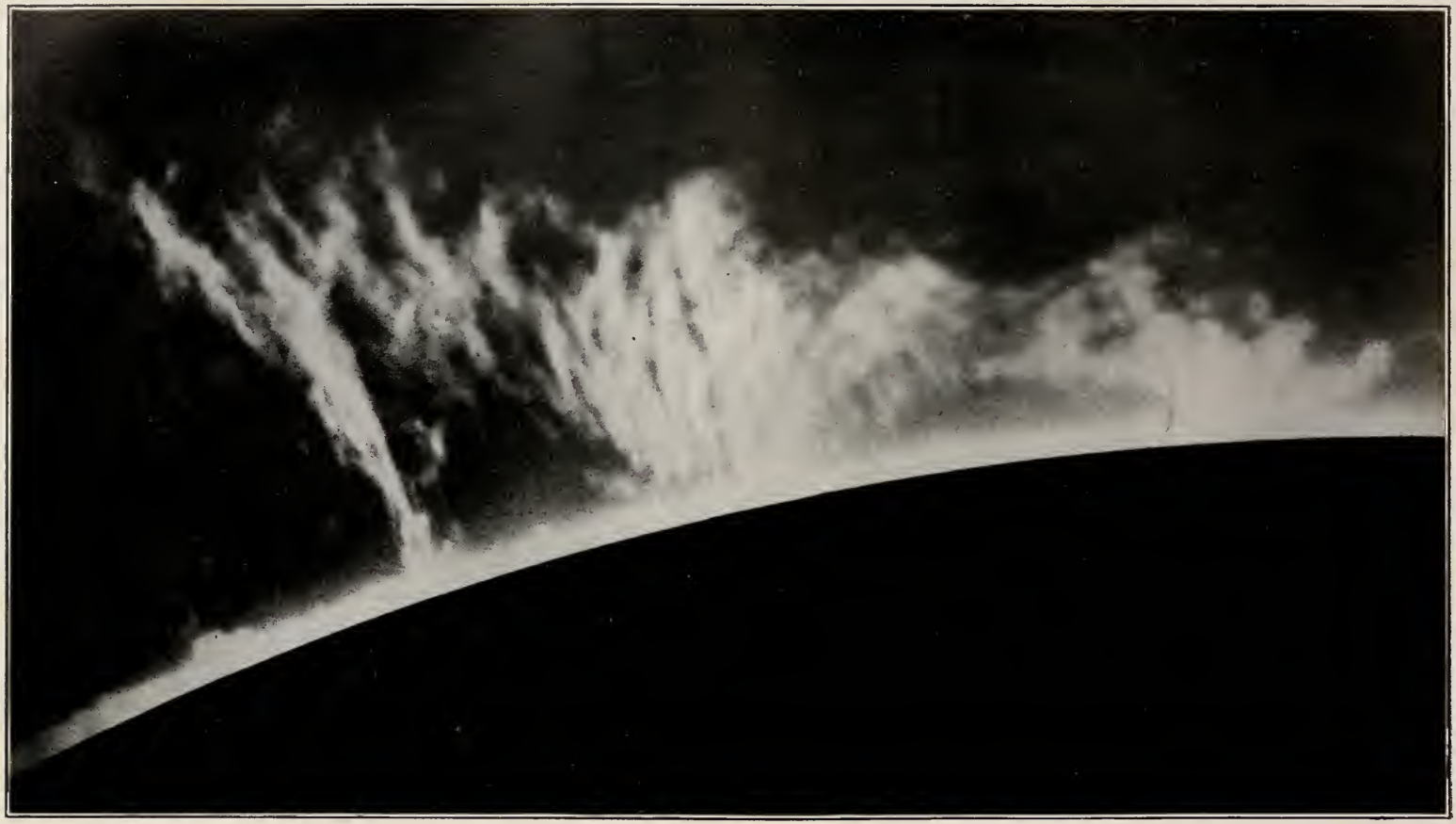
Mr. W. S. Adams retained his position as superintendent of the computing division until August 1, and served as Acting Director during the absence of the Director in Europe, in April, May, and June. He now has charge of the newly-organized Department of Stellar Spectroscopy. Prof. F. H. Seares, formerly Professor of Astronomy and Director of the Laws Observatory of the University of Missouri, was appointed superintendent of the computing division on August 1. Mr. Seares will also have editorial charge of the Observatory publications, and will carry on researches in stellar photometry and other subjects. Dr. Arthur S. King has continued throughout the year his work as superintendent of the physical laboratory. Mr. G. W. Ritchey remained superintendent of construction until January 1, when the general duties of that position were assumed by the Director. Mr. Ritchey has been given charge of the work of designing and constructing the 100-inch Hooker telescope, and will also continue to direct the work of the optical shop. Mr. Ferdinand Ellerman has continued his work with the spectroheliographs

of the Snow and tower telescopes. Dr. C. E. St. John has been engaged in an investigation of the radial motion of the calcium vapor in the solar atmosphere. He has also studied the elliptical polarization produced by the mirrors of the tower telescope, and has made some of the daily photographs of the sun with the 5-foot spectroheliograph. Mr. H. D. Babcock, formerly of the National Bureau of Standards, who was appointed a member of the staff on February 1, has been occupied principally with stellar photography and spectrographic observations with the 60-inch reflector. Dr. E. A. Fath, formerly of the Lick Observatory, began work on July 1. He will devote most of his time, for the present, to a photographic study of the spectra of nebulæ and star-clusters and a spectrographic survey of stars in Kapteyn's Selected Areas. Dr. C. M. Olmsted has continued his laboratory work in Pasadena. Mr. W. I. Way has assisted in making the daily series of photographs with the 5-foot spectroheliograph. Miss Ware, Miss Lasby, Miss Smith, Miss Burwell, and Miss Wickham have continued the measurement of photographs and the other duties of the computing division. Miss E. Phœbe Waterman joined the computing division on January 1.

Prof. J. C. Kapteyn, of the University of Groningen, Research Associate of the Carnegie Institution of Washington, spent three months on Mount Wilson in the autumn of 1908 and returned in July, 1909, to continue his work. Dr. H. G. Gale, Assistant Professor of Physics at the University of Chicago and Research Associate of the Carnegie Institution of Washington, began an investigation of the spark-spectra of metals under pressure, in connection with the spectrum of the sun's limb, in March, 1909. Prof. Ernest F. Nichols, Research Associate of the Carnegie Institution of Washington, had expected to spend the summer of 1909 on Mount Wilson. He was prevented from doing so, however, because of his appointment as president of Dartmouth College. Dr. Giorgio Abetti, of the Osservatorio di Arcetri, Florence, spent five months on Mount Wilson during the winter and spring of 1909, as a volunteer assistant engaged chiefly in solar research. Mr. Kristian Lows, of Copenhagen, stayed several weeks on Mount Wilson during the summer of 1909, assisting in computing, etc. Dr. C. W. Chamberlain, Professor of Physics at Vassar College, carried on special research at the Mount Wilson laboratory during August, 1909.

During the autumn of 1908 a permanent concrete building was erected by the Smithsonian Institution on a piece of our property on Mount Wilson, leased by the Carnegie Institution of Washington for that purpose. In this building all of the instruments, formerly used by Mr. Abbot and his assistants in temporary structures, are now mounted. The work of the Smithsonian Expedition during the present season was begun by Mr. Abbot in May and will continue until November. Dr. Leonard R. Ingersoll, Assistant Professor of Physics at the University of Wisconsin, has assisted Mr. Abbot in making the observations.

PLATE 9



Solar Prominence, 85,000 Miles High. Photographed with the Snow Telescope and 5-foot Spectroheliograph, August 21, 1909.

INVESTIGATIONS IN PROGRESS.

SOLAR RESEARCH.

Direct Photography of the Sun.

Direct photographs of the sun have been made on every clear day with the Snow telescope, as in previous years.

Work with the Spectroheliograph.

During the year 1,180 photographs of the sun have been made with the 5-foot spectroheliograph of the Snow telescope. The great advantages offered by the $H\alpha$ line of hydrogen for the study of the solar vortices were mentioned in the last annual report. For the purposes of the daily record, two photographs of the entire disk are ordinarily taken with this line and when the conditions are favorable an additional series of photographs of interesting regions is also made. In the study of these plates it has been found that the changes in form of the $H\alpha$ hydrogen flocculi are so rapid that photographs separated by an interval of 8 or 10 hours can not safely be employed for the study of the solar rotation. With the Snow telescope, sharply defined images of the sun are obtained only during short intervals in the early morning and late afternoon. Consequently, it has been necessary to postpone a further investigation of the solar rotation, as determined by the motions of the $H\alpha$ flocculi, until arrangements have been made for observations of this kind with the tower telescope.

It is evident, however, from studies of the changes in form and intensity of the hydrogen flocculi, that the problem of finding objects suitable for measurement in this research will not be a simple one. A series of 50 photographs, taken at intervals of about 1 minute, and examined directly or with an Edison kinetoscope, affords excellent material for tracing the rapid changes of the flocculi near sun-spots. It may be said, in general, that distinct evidence of motion along the apparent stream-lines is not usually afforded by such a series. On June 3, 1908, a great mass of dark hydrogen was suddenly swept into a sun-spot, and the various phases of the phenomenon were well shown by the photographs. Nevertheless, it is now evident that such an event is to be regarded as exceptional. In fact, it appears probable that the changes in the flocculi are frequently due to variations in the temperature, depth, or density of the hydrogen gas, rather than to motion of the gas along the stream-lines of a vortex. Dr. Abetti devoted much of his time to work on this subject.

In the elucidation of these phenomena, the 30-foot spectroheliograph, erected in the autumn of 1908, for use with the 60-foot tower telescope, has proved highly advantageous. In this instrument the collimator and camera slits are fixed in position and the motion of the solar image is produced by a system of three plane mirrors, mounted above the collimator slit, and moved across it by means of an electric motor. A 60° liquid prism, a 64° glass

prism, and an 8-inch plane grating can be used in this spectroheliograph. Thus a wide range of dispersion is available for different classes of work. In one arrangement of the apparatus, two spectra of the same region of the sun are formed side by side, with light from a single collimator slit. Thus simultaneous photographs of the same region can be taken with light from the red and violet edges of the $H\alpha$ line, for example. Such photographs are being used in an investigation of the possible effect of anomalous refraction on the flocculi.

In harmony with the results of Deslandres, photographs of the flocculi made with different parts of the $H\alpha$ line show different structure corresponding to different levels. The vortices are well photographed when the camera-slit is set so as to include the edges of the line. But M. Deslandres is not thereby justified in drawing the following conclusion:

"l'apparition des plages faculaires noires, annoncée depuis 1903, est due, au moins pour une large part, non à des particularités dans le pouvoir émissif ou absorbant de l'hydrogène, mais à une simple cause instrumentale, à un défaut primordial du spectrohéliographe qui, ayant une fente de largeur constante, ne peut isoler complètement une raie de largeur variable." (Comptes Rendus, 10 Mai, 1909.)

If the $H\alpha$ line is due to absorption, the dark flocculi photographed with light from its edges represent regions of increased absorption. Moreover, the possibility of photographing such regions (even if it depended solely upon variations in the width of the line, which is not the case) should not be regarded as a "defect" of the spectroheliograph, but rather as one of its most valuable properties.

The dark filaments, as well as the bright flocculi, are given by the light from the center of the line. A study of the width, intensity, and structure of the $H\alpha$ line in various parts of the sun's disk has been made in the third order of the grating.

Although the vortex structure (except as it appears in the larger filaments) is better shown near the edges than at the center of $H\alpha$, it is easily photographed with the camera slit of the 30-foot spectroheliograph set at the center of $H\beta$ or $H\gamma$. Moreover, $H\beta$ now gives admirable photographs of the vortices with the 5-foot spectroheliograph. $H\gamma$, however, fails to bring out the finer stream-lines, and therefore does not give the complete structure, though many of the stronger stream-lines appear. Further investigations are in progress.

Spectra of Sun-spots.

In my last annual report it was stated that the work at that time accomplished on the spectra of sun-spots indicated the probable existence in these regions of strong magnetic fields. This investigation has been continued and

the results prove conclusively that great electric and magnetic phenomena play an important part in the sun. The results of the observations thus far completed may be summarized as follows:

(1) In the spectra of sun-spots most of the Fraunhofer lines are widened, some are changed to doublets (incompletely resolved quadruplets), and some to triplets. Others probably have a still more complex structure.

(2) The component lines of spot doublets are circularly (or elliptically) polarized in opposite directions (longitudinal effect in a magnetic field.)

(3) Many lines not resolved in the spot spectrum are displaced when the nicol (used with a Fresnel rhomb before the spectrograph slit) is rotated.

(4) When the nicol, used with rhomb, is set at a certain angle, it transmits the red components of doublets in the spectrum of a right-handed vortex and the violet components in a left-handed vortex.

(5) Although the larger spots in the northern and southern hemispheres of the sun are usually found to be of opposite polarity, it frequently happens that spots of opposite polarity occur in the same hemisphere, often in the same spot-group.

(6) Triplets have been found in all our best photographs of spot-spectra, including those taken when the spot was near the center of the sun.

(7) The central component of such triplets is plane polarized, while the outer components are elliptically polarized.

(8) Many lines which are widened but not resolved in spot-spectra can be shown to be triplets by cutting out the central component with a nicol placed at a suitable angle.

(9) Under certain conditions, when a nicol is used, the central line of a spot triplet is present on one side of the spot and absent on the other. Rotation of the nicol through 90° reverses the appearance, causing the line to appear on the side where it was previously absent and to disappear on the opposite side. This effect is provisionally attributed to a rotation of the plane of polarization of the plane polarized light emitted by the central line, when passing outward through the spot-vapors.

(10) The width of the components of a spot triplet sometimes varies with the position of the nicol. This may be the result of the combined effect of the rotation of the plane of polarization and the rapid decrease upward in the strength of the field above the spot.

(11) The intensity of the central line of a spot triplet varies with the position of the spot on the sun's surface, and is greatest near the limb.

(12) The intensity of the central line of a triplet in a spot near the center of the sun is such as to indicate that the lines of force of the magnetic field usually make a considerable angle with the solar radius passing through the spot.

(13) Lines which appear as doublets in the spot-spectrum are found in the laboratory to be doublets when observed along the lines of force, and

quadruplets when observed across the lines of force. With the dispersion available, such lines can not be resolved into quadruplets in the spot-spectrum.

(14) Spot triplets are found in the laboratory to be triplets when observed across the lines of force.

(15) Certain triplets and quadruplets of iron show nearly the same relative separation of their components in spot and laboratory.

(16) From the measurement of such lines, the maximum strength of the field is found to range from about 2,900 to about 4,500 c. g. s. units in different spots.

(17) The strength of the field is generally greatest near the center of the umbra and decreases gradually in intensity across the penumbra.

(18) An appreciable field is shown by certain lines to extend beyond the boundaries of the penumbra.

(19) Magnetic fields have also been found on the solar disk entirely outside of sun-spots.

(20) The doublets and triplets of iron give the strongest fields hitherto measured in sun-spots. The D lines of sodium and the *b* lines of magnesium, which are produced at a higher level in the solar atmosphere, usually indicate a much weaker field. The hydrogen lines over sun-spots, representing a still higher level, give no indication of a magnetic field. It therefore follows that the strength of the field in sun-spots rapidly decreases in passing upward from the surface of the photosphere.

(21) Preston's law, $\frac{\Delta\lambda}{\lambda^2} =$ const., is approximately followed by iron doublets observed in the laboratory (using mean values of $\Delta\lambda$) and less accurately so by spot doublets.

(22) The degree of widening of unresolved lines in the spot-spectrum decreases rapidly from the red to the violet, and is roughly proportional to the separation of their components in the laboratory.

(23) A direct relationship appears to exist between the strengthening and the widening of lines in spot-spectra.

(24) As the strength of the field is greatest at low levels, it appears probable that the electric vortex which produces the field lies within the photosphere.

(25) The strength of the field in sun-spots is not sufficient to account for magnetic storms on the earth.

I am continuing the investigation with the 60-foot tower telescope on Mount Wilson, and Dr. King, who has done all of the laboratory work, is making an extensive study of the Zeeman effect in Pasadena. As soon as the 150-foot tower telescope and the 75-foot spectrograph are completed, it should be possible to obtain many new results.

Mr. Adams, aided by members of the computing division, has completed a catalogue of about 14,000 lines in the spectra of sun-spots. Dr. King has

continued in the laboratory the study of the behavior of these lines in an electric furnace, with results in harmony with the hypothesis that the relative intensities of the spot-lines are determined by the reduced temperature of the spot-vapors. Mr. Ellerman is preparing a new photographic map of the spot-spectrum, to replace the provisional map issued to members of the International Solar Union in 1907.

Photographic Comparison of the Spectra of the Center and Limb of the Sun.

Mr. Adams has continued his comparative study of the spectra of the center and limb of the sun, and a special study of certain phases of this problem was undertaken by Dr. Gale last spring. As the enhanced lines had been found by Mr. Adams to be relatively displaced more than other lines at the sun's limb, it became necessary to study their displacements in the laboratory, using a spark in a gaseous atmosphere under pressure. This laboratory work had been well started by Dr. Gale when he most unfortunately came in contact with the high-potential wires of the transformer used to produce the spark. The shock, though not fatal, was a very serious one, and Dr. Gale has only recently recovered from the severe burns he received. The work will be taken up again as soon as possible.

Photographic Investigation of the "Flash" Spectrum.

In view of experiments made at the Kenwood and Yerkes observatories, it seemed probable that the spectrum of the lower chromosphere, hitherto photographed only at eclipses as the "flash" spectrum, could be studied at any time in full sunlight, provided the instrumental and atmospheric conditions were favorable. With the 60-foot tower telescope it has already been possible to photograph a great number of bright lines in various regions of the spot-spectrum, including the numerous lines of the green carbon fluting, only a part of which has been obtained at eclipses. A catalogue of the lines hitherto photographed is now being prepared by Mr. Adams. The wave-lengths can be measured much more accurately than on eclipse plates, because of the high dispersion of the 30-foot spectrograph. The work will be continued to much better advantage when the 150-foot tower telescope has been completed.

Spectrographic Investigation of the Solar Rotation.

The continuation of Mr. Adams's work on the rotation of the sun during 1908 has led to the following conclusions:

(1) Observations of the rotation of the sun during 1908 give values agreeing closely with those of 1906-07 between latitudes 0° and 50°. Above 50° they give larger values, the difference in linear velocity reaching at a maximum 0.036 km.

(2) The general agreement of the results and the excellent accord with Dunér's values are opposed to the existence of a variation in the rotation rate

between 1906 and 1908. If any such variation exists, it is confined to the higher latitudes, and does not appear in the zones of greatest spot activity. The results are also opposed to a three-year period of variation, such as was obtained by Halm from a comparison of his values with those of Dunér.

(3) The observations of 1908 confirm those of 1906-07 in showing that different lines give different velocities. Lines of lanthanum and cyanogen give low velocities; certain lines of manganese and iron give high velocities. The investigation of two "enhanced" lines indicates a tendency toward low values for lines of this type. In one of the cases this effect is very marked. Lines considerably strengthened at the sun's limb give high values in general.

(4) When lines give systematically large or small values for the rotational velocity the differences from the mean become greater toward higher latitudes.

(5) The results given by the 1908 observations are satisfied within the limits of accidental error by the equation given by Faye for the motion of the sun-spots observed by Carrington. The fact that the observations of Dunér, Halm, and Adams are all satisfied by this equation indicates that it represents the law of rotation of the sun's reversing layer to within at least 10° of the pole.

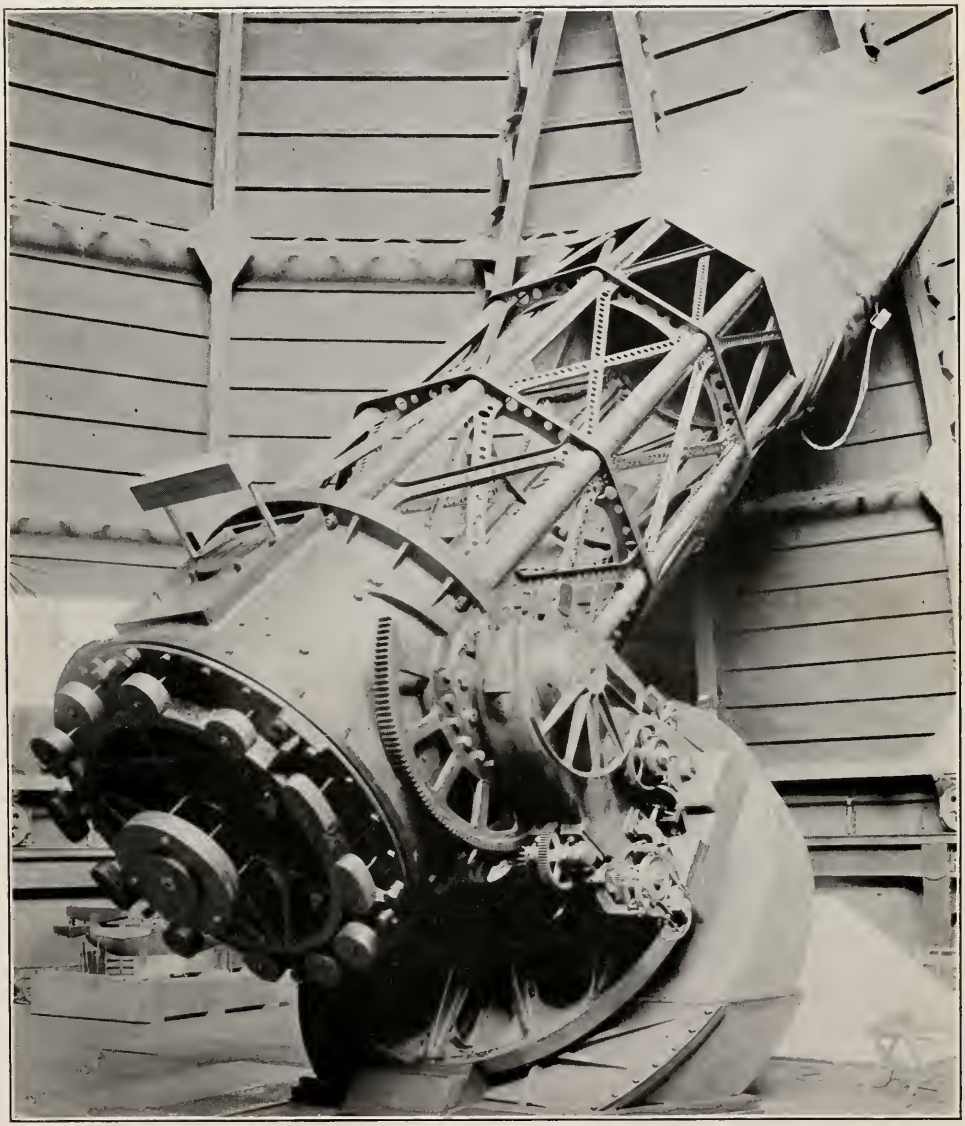
(6) Comparison of the probable errors for the two series of observations indicates a substantial gain in accuracy of measurement for the 1908 series over that of 1906-07.

(7) The motion of the reversing layer in the vicinity of solar vortices may be seriously influenced by the motion of the vortices, and the rotational velocities obtained from such regions are subject to large systematic errors. It is important in taking observations for rotation to avoid all such disturbed areas.

(8) A special study of the calcium line λ 4227 shows that the rotational velocity derived from this line is higher than that for the general reversing layer, the difference at the equator amounting to 0.3°. Also, the decrease of velocity with increasing latitude is much less marked than for the reversing layer. At 75° of latitude the angular velocity of λ 4227 is 1.5° greater than for the reversing layer.

(9) A special study of the $H\alpha$ line of hydrogen shows that the rotational velocities which it gives depend upon the distance from the sun's limb. Results obtained from $H\alpha$ at the limb of the sun are considerably larger than those for the reversing layer and show a comparatively small decrease in the value of the angular velocity toward the pole. At the equator the difference from the reversing layer amounts to 0.6° and at 75° of latitude to 3.0°.

(10) At a distance averaging 35″ inside the sun's limb the results obtained from $H\alpha$ are considerably smaller than the corresponding values at the limb, although still much larger than for the reversing layer. They also average somewhat larger than for λ 4227.



60-INCH REFLECTING TELESCOPE.

(11) The sudden increase in angular velocity at latitude 75° may perhaps be a genuine effect similar to that found among the lines of the reversing layer which gives systematic deviations.

(12) The large rotational values given by λ 4227 and *Hα*, and the differences found for *Hα* at the limb and inside the limb, may be accounted for on the basis of differences of level in the solar atmosphere.

Radial Motion of the Calcium Vapor in the Solar Atmosphere.

An extensive study of the motion of the calcium vapor in the flocculi has been made by Dr. St. John. The instrument used for this purpose is the 18-foot spectrograph of the Snow telescope, provided with an attachment by which successive images of the H or K line, corresponding to adjoining regions of the solar image, can be photographed in the third spectrum of an 8-inch Michelson grating. The positions of the H_2 and K_2 and the H_3 and K_3 lines have been measured on a large number of plates and the results are now being reduced for publication.

Areas and Distribution of Prominences.

Dr. Abetti has made an extended investigation of the areas and the distribution in latitude of the prominences shown by the series of plates taken daily with the 5-foot spectroheliograph and Snow telescope. Although the observations included in the discussion cover several hundred days, the interval is of course too short to give any reliable information as to periodic variations in the areas or distribution of the prominences. There is evidence, however, for believing that the calcium (H) prominences are on the average higher than those shown by the hydrogen (Hα) rays.

Spectrum of the Zodiacal Light.

Dr. Fath has continued his observations on the spectrum of the zodiacal light, which were begun at the Lick Observatory. A cumulative exposure of $12^h\ 31^m$ with the spectroheliograph used at Mount Hamilton, and kindly loaned by Professor Campbell for a continuation of the observations, gave a spectrum which resembles the solar spectrum exactly in so far as can be judged from so small an object. Two lines are shown with certainty. These have been identified with G and a blend of the H and K lines of the solar spectrum. A comparison sky spectrum secured under the same conditions shows only these lines within the limits of spectrum obtained on the zodiacal light plate. There is no indication of bright lines on the zodiacal light spectrogram. The evidence therefore indicates strongly that the zodiacal light is reflected sunlight.

THE SIXTY-INCH REFLECTOR.

The 60-inch reflector was completed and first used for visual and photographic observations in December, 1908. It was apparent from the outset

that the performance of this telescope, both optically and mechanically, would probably meet our highest expectations. Nevertheless, the excellence of the instrument from a photographic standpoint could not be completely determined until provision had been made for protection of the telescope against changes of temperature. This was done by Professor Ritchey, in the summer of 1909, by covering the dome with a canvas screen, supported on a skeleton framework of iron pipe, and also by providing a canopy, made largely of blankets, for inclosing the greater part of the mounting during the day. The effect of the canvas screen was to reduce the average temperature range in the dome from about 21° F. to about 10° F. The canopy reduced the range to only about 3.8° F. The shutter, which is practically air-tight, is closed at the end of the night observations. It is not opened again until shortly before sunset. In the earlier part of the evening a narrow zone at the edge of the mirror, about 3.5 inches wide, is shown by the knife-edge test to be slightly turned up. For work requiring the most perfect definition, this zone is covered by a diaphragm. After midnight the figure of the mirror is usually as perfect as when it was tested in the optical shop.

As the 60-inch reflector is the largest photographic telescope in use, it is of interest to compare its performance with that of other instruments. Visually, the images of stars, planets, and nebulæ obtained with it on a good night are excellent. The star images are very small and sharp and can be focused with great precision. Such an object as the Great Nebula in *Orion* shows a bewildering variety of detail. Globular star clusters are especially ramarkable, because of the large number of stars made visible by the great light-gathering power. However, the telescope has been so constantly employed for photographic work that it has been necessary to postpone a complete visual test until a favorable opportunity presents itself.

Professor Ritchey's photographic experiments with the 60-inch reflector have led to a steady decrease in the diameter of the star images on the plate, and an improved plate-carrier, now under construction, will undoubtedly yield still better results. Nevertheless, it may be of interest to give some measures by Professor Seares of the star images on some of these preliminary photographs and on negatives obtained by Professor Parkhurst with the 24-inch reflector of the Yerkes Observatory. The mean diameter of the faintest star images suitable for measurement, on four good negatives (Lumière Sigma plates) made with the latter instrument, is 3.2″. On one of these plates, taken under very exceptional conditions, the diameter of the smallest images is 2.6″. For two of these photographs the Yerkes reflector was stopped down to an aperture of 18 inches.

The focal length of the 24-inch reflector is nearly 8 feet, while that of the 60-inch reflector is 25 feet. The mean diameter of the faintest star images, on two negatives (Seed 23 plates) taken with the 60-inch on good nights, is

1.3″. While these preliminary data are not strictly comparable, on account of the different kinds of plates employed, they at least show that the 60-inch is already yielding excellent images. Their quality is best illustrated by Professor Ritchey's recent photographs of nebulæ, some of which will soon be published.

Through the kindness of Professor Campbell and Professor Parkhurst, a series of comparative tests of the 24-inch Yerkes reflector, the 36-inch Crossley reflector, and the 60-inch Mount Wilson reflector will be made in the near future.

The observing program for the 60-inch reflector is not yet definitely arranged. For present purposes, the work so far accomplished may be classified as follows:

Stellar Photography.

With the Newtonian arrangement of mirrors, a large number of photographs has been taken in the principal focus for use in connection with Professor Kapteyn's studies of the stars in his Selected Areas. A number of the earlier photographs were made by Dr. Abetti, but since March, 1909, all of this work has been done by Mr. Babcock. The negatives obtained include 39 photographs of stars in the Selected Areas, 12 photographs containing focal and extra-focal images of clusters and comparison stars, made with and without a red screen, for the determination of the absorption of light in space; 5 photographs of stars for the determination of the absorption in space, taken with and without a red screen; 12 parallax plates, each having two exposures; 8 photographs of stars at the pole; and a number of miscellaneous plates for various purposes.

Parallax Investigations.

In order to gain some idea of the precision obtainable in parallax determinations made by the method of Kapteyn with the 60-inch reflector, a series of test plates was made in the Newtonian focus of this instrument by Mr. Babcock. Five of these plates were measured by Miss Ware, and from a discussion of the results by Professor Seares it seems likely that parallaxes can be determined with the 60-inch reflector with a probable error not exceeding 0″.016. There is every reason to believe that the use of the 100-foot focus combination will afford results of an even higher degree of precision.

Photography of Nebulæ and Star Clusters.

Professor Ritchey has devoted all of his nights with the 60-inch reflector to the photography of nebulæ and star clusters, both in the principal focus and with the Cassegrainian combination having an equivalent focal length of 100 feet. Much time has necessarily been spent in experimenting, in order to obtain the best means of guiding and focusing and of eliminating difficulties arising from changes of focal length of the telescope during the exposure.

By the use of a knife-edge, employed as in the Foucault method of testing the figure of mirrors, Professor Ritchey finds no difficulty in determining the focal plane within 0.001 inch. As this is only $\frac{1}{300000}$ of the focal length, such precision is most satisfactory. If the focal length changes during the exposure, the plate-holder is removed from time to time and the knife-edge employed to refocus. The evidence goes to show that the changes in focal length are due mainly to the expansion and contraction of the tube, and not to the 60-inch mirror. Hence the scale of the image does not change, if the plate is kept at a fixed distance from the mirror.

The nebulæ thus far photographed in the principal focus include the Great Nebula in *Orion,* the Great Nebula in *Andromeda,* the *Pleiades,* the Ring Nebula in *Lyra,* the Dumb-bell Nebula *N. G. C.* 6960, *N. G. C.* 6992, M. 33 *Trianguli,* and M. 1 *Tauri.*

As yet there has been little opportunity for photography with the Cassegrainian combination of 100 feet focal length, but the results obtained are most encouraging. From an optical standpoint, this arrangement has been found perfectly satisfactory. The star images are so sharp and symmetrical as to leave no doubt regarding the excellence of the figure of the hyperboloidal mirror and that of the plane mirror at the intersection of the polar and declination axes.

Stellar Spectroscopy.

It has long been my purpose to photograph the spectra of the brighter stars on the scale of the negatives used in making Rowland's map of the solar spectrum. The solution of this problem would render possible the determination of the pressure existing in stellar atmospheres, and many other investigations which are beyond the reach of existing stellar spectrographs. Experiments with this end in view were accordingly begun at the Yerkes Observatory in 1901. These were continued by Mr. Adams and myself on Mount Wilson in 1905, with the aid of the Snow telescope. The results of this work have already been published (Contributions from the Mount Wilson Solar Observatory, Nos. 8 and 12). In the design of the mounting of the 60-inch reflector, provision was made, in one of the Cassegrainian combinations, to send the light down through the polar axis, after reflection at a plane mirror mounted at the intersection of the polar and declination axes. The star image is thus formed at a point some distance below the lower extremity of the polar axis; the equivalent focal length of the mirror system is 150 feet. The spectrograph employed to photograph this image may be mounted within a concrete house, on a pier whose upper surface is parallel to the polar axis. A different arrangement permits the use of a vertical spectrograph, in which the prism or grating is mounted in a constant temperature chamber about 14 feet below the level of the

ground. In this case the light is reflected vertically downward by means of a small plane mirror, supported below the end of the polar axis.

This second arrangement has been used for the experiments so far accomplished. The spectrograph, which is of the Littrow form, has an aperture of 6 inches and a focal length of 18 feet. The electric slow motions of the 60-inch reflector are under the control of the observer, who watches the star image reflected from the polished slit jaws. As these slow motions work very perfectly, and as the convex mirror can also be focused by a small electric motor operated from the same point, it is easy to keep the star image on the slit throughout the exposure.

In the first experiments, which have been made by Mr. Adams, Mr. Babcock and myself, the spectra of *Arcturus* and *Antares* have been photographed with a 64° dense flint prism, twice traversed by the light. This prism, though the largest available, utilizes only a part of the beam. A liquid prism, having faces 12 inches in diameter, is being tested in the hope that it may serve for this purpose.

In spite of unfavorable conditions, which can be avoided in later work, some of the photographs are of fair quality. A discussion of the results must be reserved until the work of measurement has been completed. It is evident, however, that the results will give a first determination of the pressure in the atmosphere of *Arcturus*.

The second spectrograph constructed for the 60-inch reflector is designed for use with the Newtonian combination, in the principal focus of the large mirror. By means of a plane mirror, the diverging rays beyond the focal plane are reflected toward the lower end of the telescope tube. They then encounter a Voigtlander portrait lens of 5 inches aperture and 15.7 inches focal length, which serves as a collimator. In this way the spectra of all stars lying within a field about 30′ in diameter can be photographed at once. As it may be difficult to get thoroughly satisfactory results without a slit, I have devised a multiple slit, by means of which the spectra of from 6 to 10 stars can be photographed simultaneously. With the aid of comparison spectra, it is hoped that the approximate radial motions and the spectral classification of the tenth and eleventh magnitude stars in the central part of Kapteyn's Selected Areas can be determined. The spectrograph is also provided with a spectroheliograph attachment, to be used in photographing comets and nebulæ with monochromatic light.

This spectrograph has been employed by Mr. Adams and Dr. Fath in photographing the spectra of star clusters and also of individual stars. The preliminary tests of the multiple-slit method are sufficiently encouraging to render advisable the construction of such a slit.

A temporary wooden spectrograph was employed with the 60-inch reflector during the winter by Mr. Adams and Mr. Babcock in various preliminary experiments.

Professor Kapteyn's Investigations.

Professor Kapteyn has presented the following account of his work on Mount Wilson. The greater part of his time has been devoted to the further investigation of the selective loss of light in its progress through space. As the investigation published last year (Contributions from the Mount Wilson Solar Observatory, No. 31) pointed to the conclusion that, other things being equal, the redness of stars must increase with their distance, the degree of redness was investigated of all the stars (over 1,400) for which reliable values of all the required data (spectrum, proper motion, photographic and visual magnitude) could be found in the existing literature.

The result finally arrived at is that the selective loss of light is certainly exceedingly small. The degree of redness, as expressed by the difference, photographic brightness—visual brightness, increases by only 1.0 per cent (0.009 magnitude) for a distance of 100 light-years. Owing to the smallness of this quantity, it is not surprising that the probable error of the result amounts to 20 per cent of the whole.

It must be acknowledged that a perfectly satisfactory treatment of the problem requires the solution of another question: Assuming the spectra of two stars of very different total light-power to show identically the same lines, does it follow that the intensities of the continuous spectra are proportional throughout their entire length? It should be possible to settle this question satisfactorily as soon as experiments can be made with this particular purpose in view. In the absence of such experiments, however, it can not be denied that some doubt must remain as to the reality and the amount of the present result.

In consideration of the fundamental importance of the problem, another method of establishing the reality of the selective loss of light is now being tried. A great difficulty of the method employed up to the present time lies in the fact that, owing to the moderate distances of the stars thus far considered, the effect of the absorption can not exceed a few hundredths of a magnitude—an effect so small that it can be clearly detected only in the average of hundreds of stars. On the supposition that space is somewhat uniformly filled with absorbing or scattering matter, this effect must, however, increase proportionally to the distance. Thus we need only take into consideration objects of sufficient distance in order to get effects which will be quite considerable.

The difficulty is that such great distances can not be measured by any known method. But there are strong reasons for supposing, however, that most, if not all, of the smaller clusters must be at distances of the required order. An attempt has therefore been made to use the enormous light-gathering power of the 60-inch reflector to obtain all the required data for a series of such objects.

Up to the present time it has been possible to make only a preliminary investigation of the four clusters for which Dr. Fath has obtained the class of spectrum. These all yield results which are decidedly confirmatory of Professor Kapteyn's expectations. The degree of redness as determined by the difference of magnitude of an object as photographed (1) directly on a Seed No. 27 plate and (2) through a Wallace red screen on a Seed No. 27 plate sensitized for the red by Wallace's process is very different from what can be accounted for simply by the class of spectrum. The differences, which have as yet been only roughly estimated, are as follows:

N. G. C. 7078 Cluster.....	1.0 mag. redder than star of same spectrum
N. G. C. 7089 Cluster.....	0.4 mag. redder than star of same spectrum
Hercules Cluster *.....	0.4 mag. redder than star of same spectrum
Nucleus of *Andromeda* Nebula.....	1.0 mag. redder than star of same spectrum

The importance of securing a method for the determination of stellar distances too great for a successful application of any existing method is obvious. An extension of this work to other objects has therefore been planned.†

Resolving Power of Gratings.

During his visit to Mount Wilson Professor Chamberlain made some preliminary tests of a device which he hopes may increase the resolving power of gratings. The work will be continued by Professor Chamberlain at Vassar College during the coming winter.

PHYSICAL LABORATORY.

The Pasadena laboratory, in which experimental work was beginning at the time of the last report, has had its efficiency increased by many additional fittings and by some new pieces of apparatus. The principal investigations carried on during the past year have been:

(1) Studies of the Zeeman effect.

(2) Electric-furnace investigations, in which the effect of temperature as a means of producing and modifying spectra was observed.

(3) A study of banded spectra, as given by the vapor of calcium and other substances when produced in an atmosphere of hydrogen.

The observations in these several lines of work have their immediate application in the study of the conditions prevailing in sun-spots, though the results obtained from the electric furnace, in particular, are useful in the general study of solar and stellar spectra and throw light besides on the temperature conditions in the radiation of various laboratory sources.

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* Dr. Fath says that the spectrum is composite. The value here given assumes that the spectrum of the cluster lies between F and K, which is probably a safe estimate.

†It is not intended to deny *a priori* that causes other than space absorption might possibly play a part in producing the observed differences. Thus, for instance, the *Andromeda* Nebula may contain matter which scatters or absorbs the light coming from the nucleus. Such points must be taken into consideration and means must be devised to eliminate them from the problem.

In the investigation of the Zeeman effect by Dr. King, magnetic fields ranging from 12,000 to 20,000 gausses were employed. High dispersion photographs of the spectra were made by means of the large grating spectrograph. Suitable adjustments of the magnet and optical system then gave means of producing numerous modifications in the resolution of the spectral lines, so that as a rule a close duplication could be obtained of the character of the separation in sun-spot lines. The kind of separation of the lines for light polarized in planes at right angles, the so-called "longitudinal" and "transverse" effects, was found to be highly important in this study, as the light from sun-spots corresponds to a mixture of these polarizations. The double lines in spot-spectra were thus found to be quadruple in the laboratory, the absence of a central component permitting the relatively weak solar magnetic field to show the doublet separation. There is also a close correspondence between the lines appearing triple in the spectra of sun-spots and in the laboratory.

The main branches of the Zeeman work have been as follows: (*a*) the measurement of the separations of components of lines in the spectra of iron, chromium, titanium, and nickel, for the comparison of the magnitude of separation and testing of Preston's Law; (*b*) determination of the plane of polarization of the light producing the several components of each line; thus for a quintuple line it is necessary to know whether the outer pair of components is produced by light vibrating parallel or perpendicular to the lines of magnetic force; (*c*) the variation in relative intensity of components polarized in different planes, produced by changing either the direction of the field or the arrangement of the observing apparatus; (*d*) the production of asymmetry in the intensity of components of separated lines by special experimental conditions which exist to a greater or less extent in the tower telescope; (*e*) the comparison of the Zeeman effect for absorption and emission spectra.

The large electric furnace has been used by Dr. King for an intensive study of the spectra of iron, chromium, titanium, vanadium, manganese, calcium, nickel, and cobalt, preliminary results of which were reported last year. These spectra, most of them having many lines, have been photographed under sufficiently high dispersion to permit an accurate study of the change in character and relative intensity of the lines as the temperature was raised from the point needed to vaporize the substance up to about 3,000° C. The range of spectrum observed was usually from λ 4000 to λ 6600. The purpose of the investigation has been not only the production of spectra by means in which temperature is the energizing agency and the comparison with spectra from other sources, such as the flame, arc, and spark, but also a study of the *rate of increase* in the intensity of lines as the temperature rises. Some lines are found to appear at low temperatures and change but slowly as the tem-

perature rises, while other lines appear at higher temperatures and strengthen at different rates with increase of temperature. The lines of each spectrum are thus classified according to their sensitiveness to temperature change. A comparison with sun-spot spectra based on this classification is being prepared for publication. A large majority of the lines relatively strong in sun-spots appear either at low temperature in the furnace or at slightly higher temperatures and, in the latter case, show a rapid rate of increase in intensity as the temperature rises. Thus the mass of spectroscopic evidence points to a relatively low temperature in sun-spots as being at any rate in large measure responsible for the differences in the spectrum of the spot and of the body of the sun.

The arc-furnace of the Moissan type has been used by Dr. Olmsted to obtain the band spectrum of calcium when vaporized in an atmosphere of hydrogen. These bands, which had been shown to be present in the spectra of sun-spots, have now been photographed on a large scale, and a full comparison made with the spot spectrum, resulting in the identification of about 600 spot-lines.

An investigation of the spectrum of the electric spark under high pressures was taken up by Dr. Gale, with reference to the shifts of solar lines at the limb and center of the sun. As already explained, however, an accident made necessary a postponement of the work.

Other investigations carried out in the laboratory include a study of the iron spectrum, which resulted in a considerable addition to the list of "enhanced" lines for iron; experiments by Mr. Babcock on the discharge conditions in a vacuum-tube as affecting the relative intensity of the hydrogen lines; and a study of the photographic Purkinje phenomenon by Dr. Fath.

A large amount of measurement and reduction in connection with the laboratory work has been done by Miss Wickham, of the Computing Division.

COMPUTING DIVISION.

The work of the computing division was continued under the direction of Mr. Adams until August 1, when Professor Seares was placed in charge.

As already stated, the continuation of Miss Ware's measurements of the hydrogen flocculi, for the determination of the solar rotation, has been postponed until better photographs can be obtained. Her work during the year has consisted mainly in the study of changes in the solar vortices and the measurement of doublets and triplets in sun-spot spectra, stellar spectra made with the 60-inch reflector and 18-foot spectrograph, and stellar photographs taken for the determination of parallaxes.

By an improvement in the method of measurement suggested by Mr. Adams, the approximate areas of the calcium flocculi have been determined by Miss Smith much more rapidly than before. Prints are made from each

negative, on heavy paper, and the flocculi selected for measurement are cut out and weighed on a delicate balance. Although the areas thus measured are systematically much smaller than those obtained by the photometric method previously employed, the two methods give curves showing the variation in the area, and thus indicating variations in the solar activity, which are very nearly parallel. After a careful comparison, made by measuring a large number of photographs by both methods, the weighing method has been adopted for future work. As it is well adapted for the determination of the areas of prominences photographed at the sun's limb, this additional work is now included in Miss Smith's regular program of measurement.

The definitive reduction of our photographs of the sun-spot spectrum has been completed by Mr. Adams and Miss Burwell, and the results are now being tabulated for publication. This has involved a very large amount of labor, as it was necessary to measure the wave-lengths and to estimate the intensities of about 11,000 sun-spot lines. The wave-lengths of about 4,900 lines in the spectrum of titanium oxide were also measured for comparison with the spot-lines. About 6,300 of the 8,100 unknown lines in the spot-spectrum have been identified with lines of titanium oxide, calcium hydride, and magnesium hydride. In addition to the above work, the separation of the components of many doublets and triplets in the spot-spectrum has been measured.

Miss Lasby has continued the measurement of plates taken by Mr. Adams for the determination of the solar rotation and the comparison of the spectra of the limb and center of the sun. She has also measured five high-dispersion photographs of the spectrum of *Arcturus*. Her work has been facilitated by the acquisition of a large measuring-machine made by Toepfer, of Potsdam.

Miss Wickham has measured photographs of the chromosphere spectrum, as well as limb and center plates. She has also devoted much time to the measurement and reduction of laboratory plates taken by Dr. King.

Miss Waterman has determined the errors of several micrometer-screws, measured photographs of spot-spectra taken for the study of the radial motions discovered by Evershed, and made many least-squares reductions.

CONSTRUCTION DIVISION.

The construction division remained under the superintendence of Professor Ritchey until January 1. Since that date, apart from observational work on Mount Wilson, he has devoted his time to the work of the optical shop and the designing of the mounting of the 100-inch reflector. The other work of construction has been done under my general supervision, with Mr. Ayers in immediate charge of the work of the instrument shop, and Mr. Jones in immediate charge of the construction work on Mount Wilson.

150-FOOT TOWER TELESCOPE, SHOWING CONSTRUCTION.

The work of erecting the 60-inch reflector in its dome was continued through the autumn of 1908 and completed early in December. Great credit is due to Professor Ritchey and all associated with him for the admirable performance, both mechanical and optical, of this powerful instrument. The excellent design and thorough construction of the mounting have eliminated all difficulties which might arise from flexure, imperfect driving, or other causes so commonly encountered in large telescopes. The figure of the mirrors is essentially perfect, and the support system is so satisfactory that the 60-inch mirror is not perceptibly distorted in any position of the telescope.

The success of the 60-inch reflector seems to leave no doubt that the 100-inch reflector will give still better results, fully in proportion to its increased aperture. Unfortunately, the glass disk, weighing 4.5 tons, which was sent to Pasadena last year, had many defects and was therefore immediately rejected. The St. Gobain firm had previously supplied us with a large number of disks, up to an aperture of 5 feet, every one of which was perfect, but in this case the flaws within the glass were so numerous that they were seen as soon as it was removed from its packing-case. The management of the glass company immediately expressed their willingness to bear the loss and to construct another disk. Professor Ritchey was sent to Paris to discuss with them the best arrangements for repeating the work, and as the result of his visit a new glass furnace, as well as a new annealing oven and other accessories, were constructed. I examined these at St. Gobain in June just after they were completed, and convinced myself that the preparations for the manufacture of another disk were adequate. At last reports some minor difficulties were still being encountered, but there is every reason to suppose that a perfect disk will soon be obtained. A very fine 60-inch disk, to be made into a plane mirror for testing the figure of the 100-inch, has recently arrived in Pasadena. The 100-inch grinding machine will be ready by the time the large disk arrives, and the optical work will be pushed forward without delay. The work of designing the mounting is advancing rapidly, and its construction can be undertaken as soon as funds become available for this purpose.

The design for the double steel tower of the 150-foot tower telescope was completed by D. H. Burnham & Co., of Chicago, early in June, and the contract for the steel let to the Morava Construction Company. All of the steel has arrived in Pasadena and the lower section of the tower is being erected on Mount Wilson. As the cœlostat, second mirror, and object-glass are to be supported at a height of 160 feet above the ground, the question of stability is important. To secure protection from the wind (the only source of vibration) each of the steel members of the tower is inclosed within the corresponding hollow members of a second skeleton tower, mounted on independent foundations. The tower carrying the instruments is thus completely

inclosed and, as it does not touch the outer tower at any part, there is no reason to doubt that it will be perfectly stable, even when considerable wind is blowing. The outer tower will carry a dome to cover the instruments at the summit and a small electric elevator to render them accessible. The combined spectrograph and spectroheliograph, of 75 feet focal-length, will be mounted in a well, with concrete walls, 10 feet inside diameter, and 78 feet deep, which is already completed. The cœlostat has been designed and is under construction in our instrument shop. Work on the combined spectrograph and spectroheliograph will begin soon.

In addition to the work of completing and mounting the 60-inch reflector and its accessories, the instrument-shop has constructed the focal-plane spectrograph and the 18-foot stellar spectrograph, apparatus for enlarging and widening specrta, and other minor instruments, besides doing much work on the 100-inch grinding-machine.

Work on Mount Wilson has included the heavy labor of opening and repairing the road from the valley, which was much damaged by landslides caused by the severe rains last winter; the erection and equipment of a new concrete powerhouse, thoroughly fireproof, provided with a 25-horsepower Fairbanks-Morse gasoline engine, a 17-kilowatt dynamo, etc.; the erection of a new storage-battery house, equipped with a battery large enough to provide power for operating the dome and mounting the 60-inch reflector, the 150-foot tower telescope, and other instruments and machinery. Wooden cottages for the engineer, night assistant, and janitor, and three small houses for night-observers were also constructed. A building for an astrophysical museum has been erected, in which a large collection of photographs illustrating the work of the Observatory will be open for public inspection. An underground chamber, with concrete walls and roof, has been provided for the variometer, which is now mounted in it. In addition to this work, a concrete laboratory and a small dwelling-house have been built by our construction force for the Smithsonian Expedition, and the 150-foot tower telescope is now being erected.

NUTRITION LABORATORY.*

Francis G. Benedict, Director.

THE LABORATORY AND ITS EQUIPMENT.

The past year has been the first in which active experimenting could be carried out in the new laboratory. The building and its equipment have proven admirably adapted for experimentation in the peculiar lines necessitated by investigations into the transformations of material and energy in the human body. The heating and ventilation of the building, the cooling appliances for the calorimeter laboratory, and the general facility with which experiments with the respiration calorimeters can be carried out all substantiate in the fullest degree the wisdom of establishing a special laboratory for these investigations. The cost of maintenance and running expenses has been such as to allow us to live within our allotment and yet accomplish more in the way of equipment, experiment, and design than was originally planned.

GRADING.

The laboratory is located on a street as yet not accepted by the city and hence is but poorly supplied with driveways. Through the courtesy of the Harvard Medical School we were enabled to make arrangements with them to use the driveway to their power-house and thence a short length of road was constructed back of the building so as to allow expressmen to drive to the rear door without difficulty. The grounds back of the building have been graded and work has been done according to plans made by a landscape architect to conform with the land adjacent to the power-house. It is hoped that provisions for a road in front of the laboratory may soon be made. A cinder footpath was placed from the door to the sidewalk on Vila Street and thus entrance can be made both in front and rear without difficulty. At present the street in front of the building is much in need of grading. Until definite plans for roadways close to the institution are made, no steps towards establishing a permanent grade may be taken to advantage.

BUILDING EQUIPMENT.

Believing that it was impracticable and distinctly undesirable to attempt to specify all the material equipment of the laboratory in the original contract, the building was so constructed that the laboratory fittings, tables, shelves, desks, etc., could be introduced as desired and as necessity demanded. Con-

*Situated at Boston, Massachusetts. Grant No. 546. $25,000 for investigations and maintenance. (For previous reports on work in nutrition see Year Books Nos. 2, 3, 4, 5, 6, and 7.)

sequently, during the past year there have been material additions to the laboratory in the shape of such fittings, several of the rooms being now completely equipped and ready for chemical experimentation. The hand-power elevator originally installed was replaced by an automatic electric elevator.

While coal-bins and the necessity for taking care of the ashes are eliminated by our excellent service from the Harvard Medical School power-house, a vacuum cleaning-apparatus has been established in order to aid in the janitor service and to minimize the amount of dust necessarily disturbed by the ordinary process of sweeping. In the original construction of the building a 2-inch vertical pipe was installed with an outlet at each floor. During the past winter a unique vacuum cleaning system of our own design has been installed at a very moderate expense. It consists of a rotary power blower which is so belted to shafting as to be run from the motor commonly used for the circular saw. A special form of water-seal trap for collecting the heavier material is placed between the blower and the stand-pipe. This water-seal trap is provided with appliances for draining off the larger amount of the dirt and flushing with water, and the small amount of dust passing through the trap is forced by the rotary blower through a pipe outdoors. The apparatus is so satisfactory that a small half-inch hose can be carried around the whole building and all dusting done by this means. For the heavier work of cleaning the floors a larger hose with a larger nozzle is employed and practically all sweeping can be done away with. The maintenance expense is small and the cost of running negligible. While at first sight it might seem unnecessary to install vacuum cleaning in a building not fitted with rugs and carpets, its practical use in the laboratory for keeping down the dust—dust which would collect on bottles, bacteriological apparatus, etc.—has been fully demonstrated.

BED CALORIMETER.

Of the five calorimeters originally planned for the calorimeter laboratory, one was completed in June, 1908. The second was completed in January, 1909, and has been used considerably during the winter and spring of 1909. This calorimeter is built on exactly the same principle as the first, but is designed to take subjects lying on a cot and can be used for sick patients as well as normal individuals. The interior is painted with white enamel and is illuminated with a small electric light, the heat developed by the lamp being deducted from the total heat measurements. The apparatus has proven remarkably sensitive and is a valuable addition to our equipment in that it enables us to extend our observations to bed-ridden patients.

TEMPERATURE RECORDER.

With a view to ultimately recording automatically as many of the numerous physical and chemical measurements as possible, a specially constructed temperature-recorder has been installed the past winter for the purpose of recording in a curve the differences in temperature of the water entering

and leaving the different calorimeters. This apparatus, which has long been planned for, was brought to a successful completion by the assistance of the Leeds & Northrup Company, of Philadelphia, whose extended experience in temperature measurements was of invaluable aid. The apparatus represents perhaps the highest type of recorder for differential temperatures thus far constructed, and the company are to be congratulated on the successful outcome of a very complex problem.

RESPIRATION APPARATUS.

Reference has been made in previous reports to the experimental work in progress on a type of respiration apparatus designed for use in hospitals in which the interchange of oxygen and carbon dioxide in the lungs could be studied. The apparatus heretofore most generally used has been that which has rendered such signal service—the apparatus of Zuntz. The great skill required in its manipulation limited its successful use to a very few persons. In the development of the respiration apparatus and calorimeters used in this laboratory, it was believed that a similar type of respiration apparatus, without calorimetric features, could be devised and used with satisfaction and not involve too great technique. This apparatus has been finally brought to successful completion, submitted to the most vigorous tests, and is now in constant use in studying problems of metabolism. It bids fair to be a most valuable adjunct to the respiration calorimeter in studying the many problems which do not warrant the costly calorimetric measurements.

MINOR APPARATUS.

The series of experiments on diabetics has called for a polariscope and special room for its use. The instrument is used for studying not only the percentage of sugar present in diabetic urine, but more particularly for studying the β-oxybutyric acid appearing in grave cases of diabetes. The room has been constructed and a specially accurate polariscope has been purchased.

In connection with thermometric measurements, an accurate cathetometer for reading mercurial thermometers has been purchased.

COOPERATING INVESTIGATORS.

During the past year a number of scientists not regularly attached to the staff of the Nutrition Laboratory have cooperated to a greater or less extent in scientific researches. During the fall of 1908, Dr. W. Falta, of the First Medical Clinic in Vienna, came to this Laboratory by means of a grant furnished especially for this purpose by the Vienna Academy of Sciences, to study the respiration apparatus and to make experiments on diabetics. Dr. Falta's brilliant researches in diabetes of animals made his suggestions and cooperation of the greatest value in the successful inauguration of an extended research on diabetes in man.

One of the foremost clinicians in Boston, Dr. Elliott P. Joslin, also became interested in the research and from the start has shown the most active spirit of cooperation. The preliminary experiments inaugurated through the cooperation of Drs. Falta and Joslin have been subsequently carried on in cooperation with Dr. Joslin during the winter, and while we are not in a position to make definite published statements, the results thus far obtained have fully justified our plans for a continuation of the research.

With a number of years' experience in most profitable experimenting on the influence of pregnancy on the metabolism of animals, Prof. J. R. Murlin, of the Cornell University Medical College, came to the Nutrition Laboratory early in May, 1909, and in cooperation with my associate, Mr. T. M. Carpenter, made an extended series of observations on the influence of pregnancy upon the metabolism of women. The experiments were conducted so as to include measurements of the total metabolism inside the calorimeter on a number of days before confinement, and several observations were made after confinement. The results proved to be of the greatest value in interpreting metabolism at this most important period of female life.

In the early part of 1909, I visited a number of American laboratories where research on nutrition and allied topics was in progress. These periodic tours are most profitable in keeping the Nutrition Laboratory in close touch with workers in this same field and also in bringing to light many points with regard to equipment and with regard to the planning of experiments.

INVESTIGATIONS NOW IN PROGRESS.

BOMB CALORIMETER.

Mr. H. L. Higgins has been engaged the past year in testing a new form of adiabatic calorimeter specially devised for use with the calorimetric bomb. Our long experience with adiabatic calorimeters, dating with the construction of the first respiration calorimeter in 1896, has led to many experiments with a view to developing a similar type of apparatus for the calorimetric bomb and thus to eliminate the lengthy and tedious calculations for the, at best, somewhat erratic cooling correction. The successful experiments of Richards, Henderson, and Frevert, in which a chemical method was used to produce adiabatic conditions about a bomb calorimeter, resulted in a most satisfactory instrument for the special work in which they were engaged. This apparatus for constant practical use in the laboratory, however, has its disadvantages, and during the past year we have developed an adiabatic calorimeter in which electrical heating is used and have thus done away with the handling of the relatively large amounts of acid and alkali required in the chemical method. The apparatus has proven most satisfactory and has been in use during the whole year. A description of it will appear in the near future.

EXPERIMENTS ON THE INFLUENCE OF THE PRECEDING DIET UPON THE RESPIRATORY EXCHANGE.

The relation between the amount of carbon dioxide excreted in the breath and the amount of oxygen absorbed gives an interesting and relatively accurate picture of the nature of the material burned in the body. Under ordinary conditions of diet, it is commonly assumed that 12 hours after the last meal the body is living substantially upon the same kind of material. This value has been designated by German investigators as the *"nüchternwert"* and is but inadequately expressed by the term "fasting value." It certainly does not represent the interchange of material after prolonged fasting. Indeed, after 48 hours, this value may be very materially changed.

In order to throw some light upon the fluctuations of this value as affected by the preceding diet, a series of experiments has been begun with the new respiration apparatus mentioned above, and a large amount of material has already been accumulated. The research will show that the ingestion of large amounts of carbohydrate, even though it be 12 hours before the experiments are made, materially influences the respiratory ratio. The experiments are still in progress, the technique has been perfected, and the results prove to be of considerable interest. The experiments are being carried out by Messrs. J. A. Riche and L. E. Emmes, of the laboratory staff.

COMPOSITION OF OUTDOOR AIR.

Innumerable analyses of outdoor air have been made by different investigators with particular reference to the carbon-dioxide and oxygen content. The variations found are very considerable. A careful inspection of the results shows that the variations may be due to the proximity to a large city, the direction of the wind, the moisture content of the air, and, above all, to the methods of analysis. As a result of a conference that I had with Mr. Sondén in Stockholm two years ago, he devised and Grave constructed for us a most intricate apparatus for the analysis of atmospheric air. During the past winter Miss Alice Johnson, of this staff, has been making a large number of analyses of outdoor air taken from either side of the laboratory building. The results show the extraordinary accuracy of the apparatus, the remarkable constancy in the amount of carbon-dioxide in the outdoor air, and the occasionally noticeable fall in the oxygen content, the cause of which has not as yet become perfectly clear.

ANALYSES OF FOOD, FECES, AND URINE OF THE ESKIMOS.

In consultation with Dr. August Krogh, of the University of Copenhagen, during my trip to Europe in 1907, a cooperative investigation into the composition of the foods, feces, and urine of Eskimos was tentatively planned. During the summer of 1908 Dr. and Mrs. Krogh went to the Danish Arctic station in Greenland and there established a portable respiration apparatus

and conducted several experiments with Eskimo men and women, in which they studied the total metabolism as indicated by the excretion of carbonic acid. In connection with these experiments, they provided constant weighed amounts of food for the subjects, and samples of the food materials were reserved for subsequent shipment. During the entire progress of the experiments the feces and urine were also saved, and these were likewise prepared and shipped, together with the foods, to the Nutrition Laboratory. In all, some 200 samples of urine, 50 of feces, and 50 of foods were received. During the past year Mr. H. L. Higgins, Miss Hope Sherman, and Miss Angelia Courtney have been engaged in the analysis of these materials. The Eskimos, subsisting as they do on a heavy meat diet, gave admirable opportunity for studying metabolism as influenced by an excessive amount of meat. The results, together with the results of Dr. Krogh's experiments, will be recorded in a publication in the near future.

THE HEATS OF COMBUSTION OF SAMPLES OF BENGALIS FOOD MATERIALS.

A most interesting memoir* has recently appeared on the diet of the Bengalis by Captain McCay, of the Calcutta Medical College. As a result of a lengthy correspondence with Captain McCay, a series of samples of common food materials as used by the Bengalis has been sent to the Laboratory and the heats of combustion of these materials have been determined. So far as we are aware, these are the first accurate determinations of the heats of combustion of these food products that have been made. They throw a definite light upon the energy consumption of the Bengalis.

DETERMINATION OF CARBON IN URINE.

The compounds in normal urine are relatively few, but very complex in their chemical structure. Under ordinary conditions every gram of nitrogen found in the urine is accompanied by not far from 0.8 gram of carbon. In determining the energy balance it is necessary to know not only the energy of the food ingested, the energy of the feces, and the heat given off from the body, but the energy of the unoxidized material of the urine is likewise of great importance. Unfortunately it is not possible to calculate with sufficient accuracy the energy present in the urine from the determination of the nitrogen, for the number of calories per gram of nitrogen may vary from 8 calories, the ordinary value, up to as high as 19; unquestionably in diabetes, where there is a large amount of sugar in the urine, this value must be still higher. It has been found, however, that the energy per gram of carbon in the urine is remarkably constant. If it is possible, therefore, to determine the

*D. McCay: Standards of the constituents of the urine and blood and the bearing of the metabolism of Bengalis on the problems of nutrition. Scientific Memoirs, n. s., No. 34, Calcutta, India. (1908.)

carbon accurately in the urine, it would be feasible to dispense with the somewhat elaborate determination of the heat of combustion of the urine which is possible only in laboratories provided with a calorimetric bomb.

To this end, therefore, an investigation has been started to determine the carbon in the urine in a relatively simple way. Prof. Charlotte Bragg, of Wellesley College, has been occupied the past winter in making some preliminary tests upon the possibility of determining carbon in urine more accurately than has hitherto been possible. In the conduct of the experiments due regard has been paid to the possibility of volatilization of the material of carbonaceous nature in pathological samples. The investigation is still in progress and the results are accordingly not ready for publication.

METABOLISM IN DIABETES.

The most important single investigation that the Laboratory has undertaken during the past winter has been that of the study of the influence of diabetes on metabolism. Stimulated by the presence of Dr. Falta, of Vienna, and by the enthusiastic cooperation of Dr. Joslin, we have been able to carry on an extended series of investigations into the total metabolism of a number of diabetic patients. The larger number of experiments have been made with the most severe cases of diabetes, although certain experiments were made with cases of varying degrees of intensity.

Of great importance has been the study of the fundamental normal metabolism of diabetics. It is contended by some that diabetics require much more energy per kilo of body-weight than do normal individuals, and the establishment of the fundamental point as to the energy transformation of diabetics was the first problem to be undertaken. It would be entirely out of place here to discuss the results, particularly as the statements of results of investigations on pathological subjects are so prone to misinterpretation. Suffice it to say that the results so far obtained have proven of decided assistance in the treatment of the several cases which have been investigated. While no startling results are looked for, it is very certain that the continuation of this research will ultimately result in a much more fundamental knowledge of this disease than has heretofore been possible.

INFLUENCE OF PREGNANCY ON METABOLISM.

The importance of a more fundamental knowledge of the metabolic processes during pregnancy has long been recognized. The difficulties incidental to such studies have precluded thus far successful experiments on this point. Thanks to the kind cooperation of Dr. Charles M. Green, of the Boston Lying-in Hospital, and Dr. J. T. Williams, who has personally been actively interested in the research, Dr. Murlin and Mr. Carpenter were able to secure patients for a series of experiments. The superintendent of the New

England Deaconess Hospital placed every facility at their disposal, and a series of respiration-calorimeter experiments was carried out with a degree of success hardly anticipated at the inception. The hospital expenses were borne by a grant made to Dr. Murlin by the Rockefeller Institute for Medical Research.

Three complete cases were studied for several days before delivery and for several days after delivery. The intra-uterine metabolism compared with the extra-uterine metabolism was sufficiently sharply studied to allow positive deductions to be drawn. The results will be published shortly.

A COMPARISON OF DIRECT VS. INDIRECT CALORIMETRY.

The Nutrition Laboratory is in a peculiarly favorable position to compare the two principal methods of studying the transformations of energy in the human body. The earlier method consisted in making chemical studies of the excreta, solid, liquid, and gaseous, and computing therefrom the kinds and amounts of material transformed in the body. From the relatively constant heat of combustion of protein, fat, and carbohydrate, it is possible to compute indirectly the heat production of man. This method has long been employed in many of the European laboratories, and in lieu of direct calorimetric measurements is of very great value. It has been believed by some, however, that for short experiments the method of indirect calorimetry is not accurate, and unfortunately the larger number of researches in indirect calorimetry have been made with experiments of short duration.

With the calorimeters available in this laboratory and with the number of different forms of respiration apparatus, it was believed that an extended investigation into the comparison of direct and indirect calorimetry should be made. From the results of the long 24-hour experiments published in the earlier reports, it has been seen that the direct and indirect calorimetry for periods of 24 hours agree perfectly as far as physiological experiments can be presumed to agree. Indications have pointed, however, to the fact that in short experiments there are relatively wide discrepancies that can not as yet be explained. A study of these discrepancies and a study into the comparison between direct and indirect calorimentry in experiments of one or two hours have occupied our attention considerably during the past year.

COMPUTATIONS.

The simultaneous determination of the large number of factors in the metabolism of man involves an extended series of calculations for each experiment, and hence the work of the computing division is of great importance in the proper calculation of the results of the different experiments. During the past year the calculation and tabulation of the results of a large

number of experiments with different individuals, with a view to studying their normal resting metabolism, have been made and brought together for publication in a report shortly to be issued by the Institution. Similarly the results of a large number of experiments on the effects of the ingestion of food on metabolism have been computed and tabulated ready for publication.

The large number of test experiments, both with the calorimeters and the respiration apparatus, necessitated by the construction of the new calorimeters, modification of parts, and the improvement of technique, has also called for a great deal of the time of the computers.

The experiments on diabetes and pregnancy have all been calculated and now only await the verification of the calculations before being ready for publication.

EDITORIAL AND PUBLICATIONS.

Since my last report the following publications have been issued. The third article was prepared for publication in 1907, but the other articles have all been written the past year.

(1) Metabolism in man with greatly diminished lung area. Thorne M. Carpenter and Francis G. Benedict. Amer. Jour. Physiol., 23, p. 412. 1909.

An experiment on a man whose left lung was completely obliterated, but who was otherwise normal, was made with a respiration calorimeter at Wesleyan University, Middletown, Connecticut. The experiment lasted 6 hours, and during this period the carbon-dioxide elimination, oxygen consumption, water vaporized, and heat production were determined. The pulse varied from 58 to 70 and the temperature was 36.67°. The naked weight was 47.3 kilos and the height 1.69 meters. The total metabolism is low, but when calculated on the basis of per kilo of body-weight and compared with the results obtained from similar experiments on other subjects somewhat approximating the weight and state of nutrition of this subject, the results show that the metabolism was substantially at the normal level for thin persons of small body-weight.

(2) Russian research in metabolism. Francis G. Benedict. Science, n. s., 29, p. 394. 1909.

During a visit to Russia I was so profoundly impressed with the amount and quality of the Russian research in metabolism that provision was made during 1908 to translate a considerable amount of Russian literature on this subject. Reference was made to these translations in my last annual report. In the article here referred to, the nature of the researches, their extent, and the publications describing the results were pointed out. It is of interest here to note that of the large book of Pashutin, of which some 800 pages relating to metabolism during inanition were translated, copies of the translation were deposited in the New York Public Library, the Library of the Surgeon-General in Washington, and the John Crerar Library in Chicago. I have already received assurances from scientific men that these translations have been much appreciated and are in use.

(3) Influence of muscular and mental work on metabolism and the efficiency of the human body as a machine. Francis G. Benedict and Thorne M. Carpenter. Bul. 208, Office of Exper. Sta., U. S. Dept. of Agriculture. 1909.

The experiments on work were made with the respiration calorimeter, and the subjects (bicycle-riders) performed large amounts of work on a stationary bicycle of peculiar construction, permitting the direct measurement of the amount of muscular work applied to the pedals. There was measured, then, simultaneously, the carbon-dioxide output, oxygen intake, heat output, and the heat of external muscular work. The subjects ranged from men who had no familiarity at all with bicycle riding, men who probably could not have ridden a bicycle on the street without considerable effort, and a highly trained professional bicycle-rider. The results are of interest in several ways, but of perhaps the most special interest was the computation of the efficiency of these men as machines.

To determine the efficiency, the resting metabolism, expressed in calories per hour, the calories produced per hour during work, and the number of calories of external muscular work performed were measured. The efficiency was computed by the formula $E=\frac{a \times 100}{b-c}$, in which a represents the heat equivalent of the external muscular work, b the total heat output during work, and c the heat output during rest. The results have been brought together in table 1.

TABLE 1.—*Results of Experiments on Muscular Work.*

[Calories per hour.]

	Resting.	Working.	Work done.	Efficiency.
				Per cent.
J. C. W.	112	339	49	21.6
B. F. D.	106	318	45	21.2
A. L. L.	105	326	46	20.8
E. F. S.	117	399	51	18.1
N. B.	92	619	112	21.3
		471	79	20.8
		401	65	21.0
		382	60	20.7

Of special interest is the fact that the professional bicycler, N. B., and the highly trained college athelete, J. C. W., on the one hand, and the wholly untrained E. F. S. and A. L. L. on the other, had substantially the same efficiency. While the professional bicycle-rider was able to do actually more work per hour, the efficiency was not materially different. The results also throw a most interesting light upon the influence of the load upon the efficiency of man. In the experiments with N. B. there was an increasing series with varying loads. Thus with an increased load resulting in an increased total heat production above the resting metabolism of 19 calories per hour, there was an increase in the work done amounting to 5 calories per hour. The increase in load was accomplished by increasing the special electrical resistances used in connection with the apparatus in that the current used to magnetize a powerful electric brake was increased.

The results are given in table 2.

TABLE 2.—*Effect of Increasing External Work on Body Efficiency.*

(*a*) Increase in magnetization from—	(*b*) Increase of total heat.	(*c*) Increase of heat of external work.	Efficiency, $\frac{c \times 100}{b}$
Amperes.	*Calories.*	*Calories.*	*Per cent.*
0.7 to 0.8	19	5	26.0
.7 to .9	89	19	21.3
.7 to 1.25	237	52	22.0
.8 to .9	70	14	20.0
.8 to 1.25	218	47	21.5
.9 to 1.25	148	33	22.3

Aside from the value for the increase from 0.7 to 0.8 ampere, *i. e.*, 26 per cent, all the results are remarkably constant, showing that the increase of load does not materially affect the efficiency of the body as a machine. Under all the conditions of work in these experiments the body was able to transmit about 21 per cent of the increased heat incidental to the increased load into heat of external muscular work.

With such a striking influence of muscular activity upon metabolism, it became of great interest to note the influence of mental work on metabolism. Recognizing the difficulties of securing sustained mental work during an experimental period of 2 to 3 hours, the best results were secured by studying the metabolism of a large number of college students while taking their mid-year examinations inside of the respiration chamber. During this period it was reasonable to assume that there was sustained mental effort. Control experiments were made several days later, and at the same time of the day and as nearly as possible under like conditions. The control experiments were so arranged as to include plain copying with the pen, with as little muscular work as possible, and the mental activity was reduced to the minimum.

Twenty-two experiments were made, and the results, together with the results of 22 control experiments, are given in table 3. There are, indeed, slight mathematical differences in the averages of the two periods, but a careful examination of the tabulated data in the original report shows that the variations between experiments were so wide that they leave no possible opportunity for assuming that mental work *per se* exercises any influence upon metabolism.

TABLE 3.—*Results of Experiments upon the Effect of Mental Work on Metabolism.*

	Quantities per hour examination period.	Quantities per hour control period.
Carbon dioxide.	33.4 grams.	32.8 grams.
Oxygen	27.3 grams.	25.9 grams.
Water vapor	39.2 grams.	37.8 grams.
Heat	98.8 calories.	98.4 calories.

(4) Mercurial poisoning of men in a respiration chamber. Thorne M. Carpenter and Francis G. Benedict. Amer. Jour. Physiol. 24, p. 187. 1909.

In the spring and fall of 1905 a number of men became ill inside the respiration chamber. The experiments were usually planned for some definite purpose, and hence the observations on the illness were only incidental. A few experiments, however, were designed specifically to study the cause of the disturbance, and after a lengthy series of observations it was traced to the toxic influence of two mercury valves used in a ventilating air-current. With the removal of these valves all toxic symptoms disappeared, and they have not recurred after a lapse of two years. The symptoms were unlike any recorded at that time for mercurial poisoning, and hence rendered the discernment of the cause of the trouble rather obscure. There was a persistent hacking cough, accompanied by a marked temperature rise and respiratory disturbance. None of the other symptoms ordinarily associated with mercurial poisoning appeared.

(5) Preliminary observations on metabolism during fever. Thorne M. Carpenter and Francis G. Benedict. Amer. Jour. Physiol. 24, p. 203. 1909.

The febrile temperature noted in many of the experiments in which mercurial poisoning was observed gave opportunity for making a number of observations on metabolism during fever. These observations included the carbonic-acid and water elimination, the oxygen consumption, and the heat elimination and production. While distinctly preliminary, and with but imperfect control experiments, the results point to a positive increase in the total metabolism during the febrile period.

(6) Automatic pipette for caustic-soda solution. Francis G. Benedict. Jour. Amer. Chem. Soc. (31), VI, p. 652. 1909.

This apparatus was introduced to minimize the handling of the rather large amounts of strong caustic-soda solution used in the Kjeldahl determination of nitrogen. It permits of the automatic delivery of any desired quantity of the liquid. The apparatus is constructed upon the principle of the displacement of a volume of liquid by a glass vessel filled with lead, allowing the displaced liquid to overflow through a side aperture. The apparatus has proven very satisfactory, and is in constant use.

(7) An apparatus for studying the respiratory exchange. Francis G. Benedict. Amer. Jour. Physiol. 24, p. 345. 1909.

This paper is introduced with an extended discussion of the significance of the respiratory quotient, the ratio between the volume of carbon dioxide exhaled and the volume of oxygen absorbed. The apparatus herein described consists of a modified form of the respiration apparatus in use with the large respiration calorimeters in this laboratory.

The subject, lying upon a cot in a comfortable position, breathes through two specially constructed nose-pieces into an air-pipe through which passes a rapidly-moving current of air free from carbon dioxide, with a humidity of about 65 per cent and with an approximately normal percentage of oxygen. This ventilating current of air is maintained by a small rotary blower, and as the expired air passes along the tube it is successively passed through sulphuric acid to remove the moisture from the lungs, through soda-lime or potash-lime to remove the carbon dioxide, and through a sulphuric-acid con-

tainer to absorb the moisture given up to the air by the soda-lime. The air is then returned to the subject for breathing, after replacing the oxygen absorbed by fresh oxygen from a cylinder of the gas. Inasmuch as the inspiration of the dry air would be irritating to the nasal passage, provision is made to moisten the air by passing it through a suitable vessel containing water. Thus the subject breathes the air again and again, the carbon dioxide being absorbed by the soda-lime, the water by the sulphuric acid, and the oxygen supplied from the cylinder. The increase in weight of the soda-lime container and the sulphuric-acid vessel indicates the amount of carbon dioxide produced, and the loss in weight of the oxygen cylinder the amount of oxygen absorbed.

The apparatus has been most critically controlled by a series of tests in which different weights of ether were burned inside of a small supplementary chamber, and likewise it has a physiological control in that subjects have alternately been tested in the respiration chamber, and also with the new apparatus. The results given by the apparatus are highly satisfactory, and it is now in constant use in connection with a series of observations on the influence of the preceding diet upon the respiratory exchange.

(8) The metabolism of man during the work of typewriting. Thorne M. Carpenter and Francis G. Benedict. Jour. Biol. Chem. (6), III, p. 271. 1909.

This article discusses in a tentative way the muscular work involved in typewriting. It is of general interest in that a large number of people gain their livelihood by typewriting, and the muscular work involved therein has never been definitely studied. Two experiments were reported in which the subjects remained inside of the calorimeter for a preliminary period without typewriting, and then during a final period wrote on an average some 1,600 words per hour. While the results given are of a tentative nature and should be amplified by further researches, they show that in general the metabolism of man is increased 25 calories per hour by the work involved in typewriting on a machine at the rate of 1,600 words per hour.

DEPARTMENT OF TERRESTRIAL MAGNETISM.*

L. A. Bauer, Director.

The fact of chief importance in the operations of the Department during the past fiscal year is, of course, the completion of a vessel, the *Carnegie,* wholly designed with the special needs for a magnetic survey of the oceans in view. The vessel was launched on June 12 and went into commission on August 21, her first work being in the North Atlantic Ocean.

Excellent progress has been made by all the field parties, the work executed being in the following countries: British North America, Central North America, West Indies, Colombia, Ecuador, British, Dutch, and French Guiana, Africa, Persia, Turkey, Asia Minor, southern Asiatic Russia, and China. In every instance the operations were conducted in regions not easily traversed and in general where either no or but very few magnetic data had been obtained previously. Special expeditions had consequently to be organized and, as will be seen from the detailed reports farther on, they terminated successfully in each case. Besides magnetic data, other information of a geographic nature has resulted.

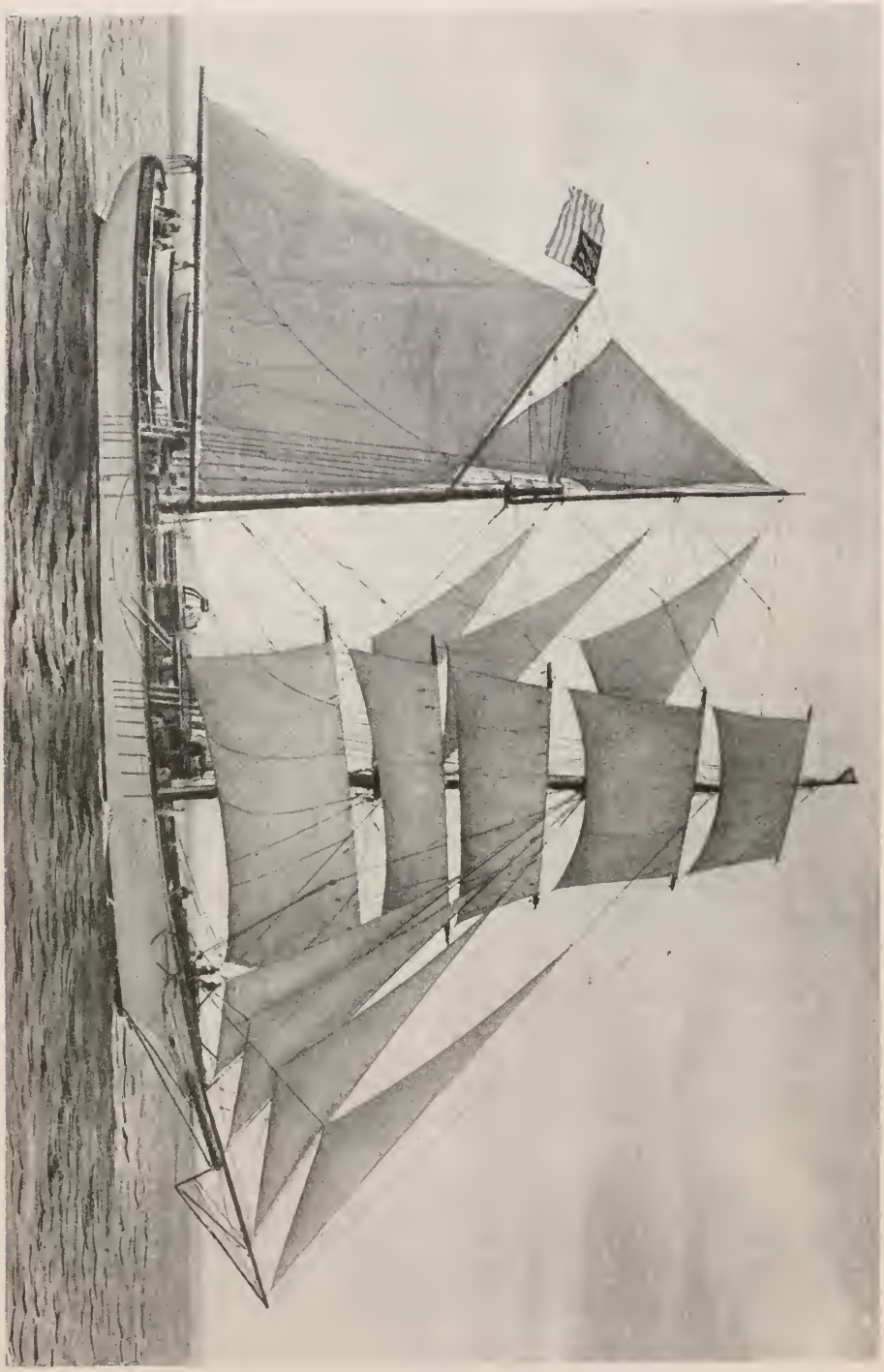
In the office at Washington, the reduction of the observations has kept pace with the field-work. However, owing largely to the construction of the *Carnegie* and of her instrumental equipment, it was not possible to complete the report of the *Galilee* work in the Pacific Ocean (1905–08), as had been hoped, but good progress has been made, and the results will soon be ready for publication. The necessity of further examination of instrumental constants and corrections likewise caused a temporary suspension of the *Galilee* reductions until the corrections were well controlled. Some special investigations, described later, were undertaken.

SYNOPSIS OF MAGNETIC WORK DURING THE YEAR NOVEMBER 1, 1908, TO OCTOBER 31, 1909.

LAND WORK.

Africa.—As stated in last year's report, the magnetic work in Africa has been intrusted to Dr. J. C. Beattie, Research Associate, who is assisted by Prof. J. T. Morrison, Magnetic Observer. Between November 1, 1908, and May 10, 1909, 40 stations were occupied in Cape Colony and 65 in German Southwest Africa. The party next proceeded from Broken Hill, Rhodesia, to Abercorn, on Lake Tanganyika, via Fort Rosebery. Tabora was reached on August 15, 92 stations being occupied en route. From Tabora Dr. Beattie expected to proceed to Entebbe, on Lake Victoria Nyanza, and thence to

* Address: The Ontario, Washington, District of Columbia. Grant No. 544. $135,000 for investigation and maintenance, and construction of vessel. (For previous reports see Year Books Nos. 3, 4, 5, 6, and 7.)



THE CARNEGIE.

Gondokoro; by the end of the fiscal year he will have occupied about 50 additional stations. From Abercorn Professor Morrison went to Chindi via Lake Nyassa, going thence to Mozambique, Dar-es-Salaam and Mombasa; he arrived at Dar-es-Salaam on September 27, 1909, and had occupied 52 stations since leaving Abercorn. By the end of the fiscal year Professor Morrison will have occupied about 20 additional stations in German East Africa and British East Africa along the railway lines from Dar-es-Salaam and Mombasa. The total number of stations in Africa for the year will hence be about 320. Such a large number of stations was made possible by the plan adopted of taking observations at each camping-place and so obtaining some knowledge as to the local magnetic conditions of the regions traversed.

Considerable assistance has been received by the party from various sources, governmental and private, the Hon. Dr. Jameson and Sir Lewis Michell contributing £100 towards the expenses of carriers in Rhodesia. The Royal Society of England furthermore has made a grant of £250 to Dr. Beattie for continuation of the work between Uganda and Egypt.

China.—From November 1 to December 15, 1908, Dr. C. K. Edmunds, of the Canton Christian College, completed the work described in the previous report, observing the magnetic elements at 3 stations in Shantung, 3 in Kiangsu, and reoccupying his station at Honglok, near Canton. He then resumed his duties with the Canton Christian College.

A special magnetic expedition in China was organized and placed in charge of Mr. Don C. Sowers. Work was begun early in December, 1908, at Canton, where the outfit previously used by Dr. Edmunds was turned over to the party and the necessary observations were made. The instruments were then compared with those of the Hongkong Observatory, the director, Mr. Figg, affording every possible assistance. Prof. Chester G. Fuson, Professor of History and Geography at the Canton Christian College, joined the expedition as chief assistant. After all preparations and observations were made at Peking, the party left on January 30 for the overland trip to Kashgar, via Chengchow, Shenchow, Sianfu, Lanchowfu, Liangchowfu, Suchow, Ansichow, Hami, Tihuafu (Urumtsi), Karashar, and Aksu. Up to Kashgar, which place was reached July 28, 57 stations had been occupied. From Kashgar the party proceeded to Khotan via Yarkand, and thence via the Sanju, Suget, Karakorum, Saser, and Khardong Passes to Leh, India, arriving there September 28, 1909. From Leh the railway at Rawal Pindi was reached via Srinagar. Comparisons of instruments were made from October 19 to 23, 1909, with the standards of the Trigonometrical Survey of India at the Dehra Dun Magnetic Observatory, and the work of the expedition closed. The total number of stations established was 73. Mr. Sowers has received cordial assistance from the various governments and their representatives, without which the expedition could not, of course, have resulted so successfully. No little credit is likewise due to the leader's resourcefulness.

South America.—At the end of the last fiscal year Mr. H. W. Fisk, Magnetician, was engaged in work in the Guianas. From November 1, 1908, to December 18, 1908, the magnetic elements were determined at 9 stations, 2 of which were in French Guiana, 3 in Dutch Guiana, 3 in British Guiana, and 1 in Trinidad (Port of Spain). Two of these stations, Georgetown (Demerara) and Port of Spain, were repeat stations.

Mr. E. Kidson, Magnetic Observer, continued the magnetic work assigned him the previous year in Ecuador and Colombia; up to June 2, 1909, he had occupied 25 stations in these countries and 3 in the Canal Zone. At 3 stations observations had been made previously, viz, Savanilla (Colombia), Colon, and Flamenco Island (Canal Zone). With this work accomplished the isomagnetic lines may be drawn with a fair degree of accuracy over the northwestern part of the South American continent.

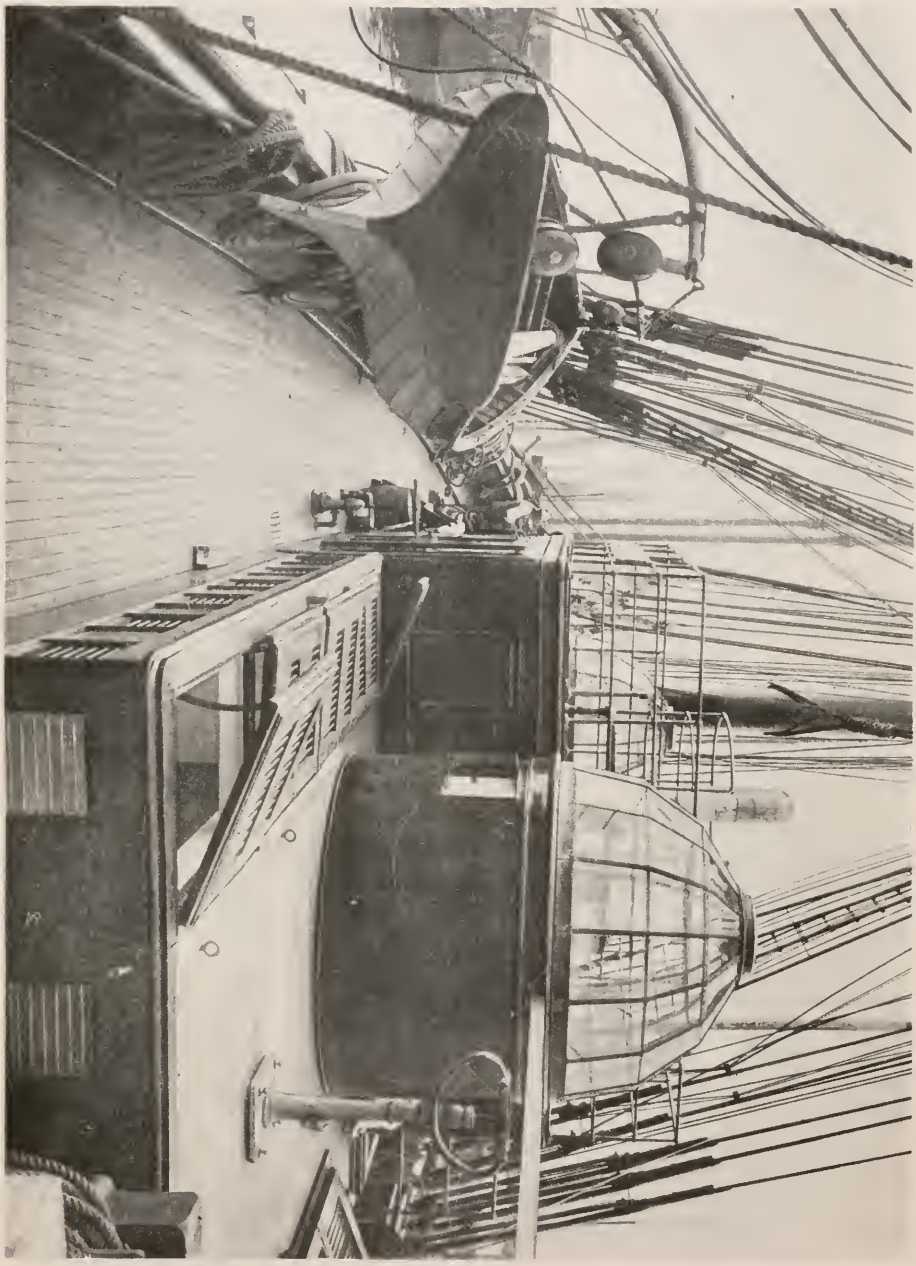
Persia, Baluchistan, Arabia, Turkey in Asia, Russia in Asia, Russia in Europe.—Mr. J. C. Pearson continued the work placed in his charge in 1908 in these countries, and up to October 31, 1909, had added 51 stations to his previous list—13 in Persia; at Gwadur, Baluchistan; 4 in Arabia; at Basra, Asia Minor; near Constantinople, Turkey; 20 in Asiatic Russia; 11 in European Russia. At several of the places results for secular variation were derived. At the beginning of the new fiscal year Mr. Pearson is at work along the southern coast of the Black Sea, in Turkey in Asia.

His instrumental outfit was again compared with the Tiflis Magnetic Observatory standards, and also with those of the Tashkent Magnetic Observatory. Owing to the unsettled condition of countries first traversed by Mr. Pearson he encountered many difficulties in travel, which he successfully overcame, very largely through the special courtesies shown him by the representatives of the Persian, Russian, English, and American governments. Acknowledgment must also be made of the substantial assistance rendered the Department, in the execution of the work in Asiatic Russia, by General M. Rykatcheff, and Director Hlasek of the Tiflis Observatory.

The work of the two expeditions—those of Messrs. Sowers and Pearson—will furnish by the end of 1909 a series of magnetic stations between parallels 30° and 40° north across the whole continent of Asia.

Central America and West Indies.—From the latter part of November, 1908, to July 14, 1909, Mr. W. H. Sligh, Magnetic Observer, made observations at 14 stations in Cuba, 3 in British Honduras, 6 in Guatemala, 7 in Honduras, 10 in Nicaragua, and 3 in Salvador. Secular variation data were obtained at several stations.

With the work previously done by the Department, the field-work necessary for a general magnetic survey of the Central American countries is almost completed. The trip from Belize, British Honduras, to Bluefields, Nicaragua, and the intermediate coast stations, was made in a small 15-ton vessel. Mr. Sligh deserves high commendation for the manner in which he



View of Deck of the Carnegie.

carried out the difficult work assigned him. Acknowledgment is due to the cordial assistance rendered by the representatives of the governments and by various private persons.

Canada, including Newfoundland and Labrador.—Mr. C. C. Stewart, Magnetic Observer, was assigned to take charge of an exploratory trip in the provinces of Ontario and Quebec, Canada. Beginning at North Bay the end of June, his trip extended to Moose Factory, James Bay, via Cochrane and Abitibi River. From Moose Factory he crossed to Rupert's House and returned via Rupert River, Lake Mistassini, Lake St. John, and Quebec. During the trip 32 stations were occupied, 6 of which were repeat stations. The field work was completed at Quebec on October 25, 1909. The providing of the facilities necessary for this important work was greatly simplified by the kind offices of the Hudson's Bay Commissioner, Mr. C. C. Chipman, and of the factor at North Bay, Mr. S. A. King. Mr. Stewart deserves much credit for the successful accomplishment of this difficult trip.

Mr. E. Kidson, Magnetic Observer, was assigned to the *Carnegie* and directed to join her at St. Johns, Newfoundland. Preparatory to this assignment, from August 1 to the end of September, he occupied a station in New Brunswick (St. John, a repeat station), one in Nova Scotia (Sydney, a repeat station), and 12 stations in Newfoundland, 2 of which, Bay of Islands and St. Johns, were repeat stations.

United States.—Mr. C. C. Stewart, Magnetic Observer, when instructing Mr. W. H. Sligh, newly appointed a magnetic observer, reoccupied with him 2 of the Maryland Geological Survey stations in Maryland, namely, Chestertown and Bowie, during the early part of November, 1908. During the latter part of November, Mr. Sligh also occupied Miami, Florida, a repeat station, and Knight's Key, Florida, while en route to the magnetic work in Cuba, as described above.

Miscellaneous.—Ten stations were also established by the *Carnegie* party in New York in connection with the instrumental tests and swings of the vessel in Gardiners Bay, Long Island, in St. Johns Harbor, Newfoundland, and off Falmouth, England.

OCEAN WORK.

The necessary appropriation having been made by the Trustees on December 8, 1908, the contract for the construction of the non-magnetic vessel *Carnegie,* briefly described in last year's report, was awarded on December 9, as the result of competition, to the Tebo Yacht Basin Company of Brooklyn, New York. The vice-president and manager of this firm, Mr. Wallace Downey, while connected with the Shooter's Island Company, built several well-known vessels, *e. g.,* the *Meteor* (Kaiser Wilhelm's yacht), and the *Atlantic,* which won the Atlantic cup race of 1906, as also the Coast Survey steamer, the *Bache,* etc.

As may be recalled, Mr. Henry J. Gielow, of New York City, had been intrusted with the preparation of the plans and specifications in consultation with the Department; he was also appointed supervising engineer.

Mr. W. J. Peters, Chief Magnetic Observer, from February 7 to August 21, 1909, was stationed at the shipyard at Brooklyn as the special representative of the Department and placed in charge of the testing of all metals used in the construction of the *Carnegie,* as regards non-magnetic properties. Owing to the care shown by the contractor and his subcontractors, very little, indeed, of the material submitted had to be rejected. Early in February, 1909, the keel of the vessel was laid, and on June 12 she was successfully launched, in the presence of about 3,500 persons, the vessels in the harbor being gaily decorated and salutes being fired as the vessel gracefully glided into the water. Miss Dorothea Louise Bauer, daughter of the Director, in compliance with the invitation from the Executive Committee of the Institution, performed the christening ceremony. After the launching the specially invited guests boarded the vessel and partook of refreshments supplied by the contractor. The occasion was a most delightful one, and one long to be remembered.

August 21 marks another eventful day in the history of the *Carnegie,* as on that day she was formally turned over to the Director, acting in behalf of the Institution, and entered upon her first cruise.

Thus in not quite 15 months since the cessation (June 1, 1908) of the ocean work begun in the Pacific Ocean on the *Galilee,* in 1905, a new and special vessel has been built and fully equipped, several of the instruments being of special design and having been constructed in the shop of the Department.

After various tests and trials in Long Island Sound and Gardiners Bay, and some machinery alterations at New London, Connecticut, the *Carnegie* left the latter place on September 11. Encountering headwinds and calms, she arrived at St. Johns, Newfoundland, on September 25, entering the harbor with her own power. Here the Director rejoined the vessel, having been obliged to leave her in Long Island Sound to attend the meeting of the British Association for the Advancement of Science. He continued with her to Falmouth, leaving her there on November 2 and then returning to Washington.

After the completion of the shore work, the *Carnegie* left St. Johns on October 2, bound for Falmouth. The passage, in general, was rough, westerly gales being an almost daily experience; still the trip was accomplished in less than 12 days, the average daily run being 161 nautical miles. Magnetic observations were secured on every day but one. On October 18 the vessel was "swung" outside of Falmouth Harbor, the results confirming those at Gardiners Bay and proving most satisfactorily that non-magnetic conditions have, indeed, been secured at the various positions for the instruments.

A.—The Carnegie.

B.—View of the Carnegie at St. John's, Newfoundland, September 30, 1909, while the mists were rolling in.

The results were also in excellent agreement with those derived from the admirable Rücker and Thorpe magnetic survey of the British Isles when referred to present date with the aid of the Falmouth Magnetic Observatory records. The Falmouth Observatory rendered valuable assistance in various ways.

Both at St. Johns and Falmouth the *Carnegie* was visited by distinguished persons—men eminent in public affairs as well as in science. Both the Governor and the Premier of Newfoundland made special visits, and at Falmouth official visits and inspections were made by Sir Arthur Rücker and Professor Arthur Schuster, both members of the Advisory Council of the Department, as also by Commander Chetwynd, superintendent of the Compass Department of the British Admiralty. Special courtesies were extended to the vessel at both ports. As she left St. Johns, messages of farewell and wishing a pleasant voyage were hoisted on H. M. S. *Brilliant* (Capt. Haworth Booth, in command) and on Cabot Tower on Signal Hill towering above the narrow entrance to the harbor.

Owing to the great advantage of having a vessel requiring no deviation corrections whatsoever, and because of the perfection reached in the instruments themselves, it was possible, for the first time, to make the results known immediately upon conclusion of a voyage. Thus the magnetic data obtained on the trip from Long Island Sound to Falmouth (September 1–October 18) were communicated at once to the leading hydrographic establishments of the world, were laid before the Russian Geographic Society at St. Petersburg by General Rykatcheff on October 27, and were published in *Nature* on October 28.

Errors of sufficient importance even to the navigator were found. Along the track followed by the Atlantic liners from England to a point off Newfoundland, the present magnetic charts, in general, show too large westerly declination (variation of the compass), the error reaching nearly a degree. Thereafter and continuing to Long Island the charts give systematically too small westerly declination or variation of the compass, by amounts reaching one degree and a half in the maximum. Owing to the peculiar and systematic nature of the errors, their effect is always to set a vessel toward Sable Island or Newfoundland when her course must be shaped entirely by the compass and the log, as is the case in time of fog or cloud. Some of the expert captains of our ocean liners have suspected the possibility of such errors, but the *Carnegie* has now definitely proved and published the fact and has revealed the cause.

The chart errors in magnetic dip may amount to one-half degree, and in the horizontal component of the magnetic force the error reaches at times nearly one-tenth part; the chart force values are in general too low by about one forty-fifth part. A part of the errors found in the three magnetic elements are due to secular variation.

[The *Carnegie* left Falmouth, under the command of Mr. Peters, on November 9 and arrived at Funchal, Madeira, on November 24. She goes next to Bermuda, and returns to New York January, 1910.]

The *Carnegie* has already attracted considerable attention, accounts of her novel construction and of her work appearing in newspapers and periodicals in many countries. The two points of special interest are:

First, the fact that she has been constructed, inclusive of her machinery, practically without iron or other metals affecting the compass.

Secondly, that a type of marine propulsion—an internal-combustion engine operated by producer-gas—has been installed as auxiliary to her sailing power, which if proved successful will be of great practical importance, since it will be the most economical form of marine propulsion now known. The difficulty of successful operation of this type of propulsion has been somewhat enhanced in the case of the *Carnegie* on account of the necessity of using almost entirely non-magnetic metals. Still, the present indications are that the problems involved will be successfully overcome.

The Department was fortunate in securing, through the courtesy of Prof. J. A. Holmes, in charge of the technological branch of the U. S. Geological Survey, the services of Mr. Carl D. Smith, expert in gas-engines, during the period of trial of the installations on the *Carnegie* in Long Island Sound and on the trip to St. Johns. Furthermore, Mr. D. F. Smith, a graduate of the University of Maine in the department of mechanical engineering, who had obtained besides practical experience in Professor Holmes's division in the operation of gas-engines, was appointed chief engineer on board the *Carnegie*.

The vessel has been described in a souvenir pamphlet prepared for distribution at the time of the launching and reprinted in the June number of the journal "Terrestrial Magnetism."

In conclusion, some reference ought to be made to the splendid cooperative spirit shown by those who had any part in the construction of the *Carnegie*. Everyone appeared to take an interest in her far beyond any purely commercial view. This was true not only of the architect and builder—the Institution having been most fortunate in their selection—but also of the various subcontractors and of the firms supplying the materials, as well as of the foreman and laborers engaged on the construction of the vessel.

Her total cost, fully equipped, was in round numbers $115,000.

The personnel of the *Carnegie* consists of the following:

Scientific staff: L. A. Bauer, director; W. J. Peters, in command of vessel; J. P. Ault, magnetician; C. C. Craft, surgeon and magnetic observer; E. Kidson, magnetic observer; R. R. Tafel, magnetic observer; D. F. Smith, chief engineer.

Sailing staff: C. E. Littlefield, sailing master; H. T. Bartlett, first officer; M. Clausen, second officer; eight seamen; one mechanic; two cooks.

OFFICE WORK.

On account of the extensive field operations in progress, as narrated above, and owing to the planning, constructing, and equipping of the *Carnegie,* the time of the office force has been necessarily largely consumed with administrative, executive, and experimental matters. The standardization of the various instrumental outfits, both for sea and land work, with the necessary accuracy, have been made as required.

The current field observations have been reduced as received, and considerable progress was made in the preparation for publication of the magnetic results thus far obtained on land and sea. The compilation of past magnetic data and the indexing of current literature have been continued, and abstracts of publications of special interest have been prepared from time to time. Letters of information and data have been supplied in response to inquiries.

STANDARDIZATION OF DIP INSTRUMENTS.

A discussion of the results obtained by the *Galilee* in the Pacific Ocean revealed the desirability of being able to examine at Washington a dip instrument within the entire range of dips likely to be observed. Thus in the Pacific Ocean this range was from $+75°$ to $-60°$. For such a large range it is an interesting as well as a practical question to find out how the correction required to reduce the results obtained to an absolute standard will vary with dip.

Accordingly a special apparatus was devised by Mr. P. H. Dike, by which, with suitable electric coils, it was possible to create the desired artificial field to produce the dip sought. A description and a first communication of the results obtained from the comparisons of the earth inductor with land and ship dip circles under such conditions was published by Mr. Dike in the issue of the journal "Terrestrial Magnetism" for September, 1909. The apparatus promises to be a useful adjunct in the study and elimination of the causes of errors of magnetic instruments.

CONSTRUCTION OF INSTRUMENTS.

The value of having a good instrument shop ready at hand has been amply demonstrated during the past year. There have been constructed a number of specially designed instruments for use on board the *Carnegie.* First among these is the collimating marine compass No. 1, after the design developed chiefly by Mr. Peters. With this instrument a greater accuracy has been obtained in the determination of declination at sea than heretofore, the observations showing an absolute accuracy under favorable conditions of about 0.05°. As a part of this instrument, a small hand circle of reflection has been specially designed and constructed. Both of these instruments will be found described in some detail in the journal "Terrestrial Magnetism" for March, 1909.

There has also been made in the shop an improved form of deflector, based on the Director's design, as already used in the cruises of the *Galilee* for the determination of horizontal intensity at sea. A description of this improved deflector has not yet been published; the observations prove that the expectations of increased accuracy have been realized. A similar deflector device has been attached to the marine collimator.

The construction of magnetometers Nos. 12, 13, and 14 has been begun, and it is hoped will be completed in the coming year. Nos. 12 and 13 have been specially designed as theodolite magnetometers of a very portable form. Each instrument, it is expected, will not weigh more than 20 pounds with its entire equipment except tripod. Magnetometer 14 is designed as a universal instrument, serving for the determination of all three elements. This instrument is also of light pattern, and will probably in its entirety not weigh more than 25 pounds.

In addition to the work as above stated the various astronomical, meteorological, and other instruments for the *Carnegie* were put in good condition.

One valuable result of the possession of an instrument shop has been in the reduction of the amount of time required to put a newly purchased instrument in satisfactory adjustment and condition for work. Above all, however, the chief value lies in the fact that the instruments may be constructed entirely under our own supervision and all metals carefully tested as to non-magnetic properties; in consequence, the instrumental corrections are being largely reduced.

Mr. J. A. Fleming had general supervision of the shop, Mr. Adolf Widmer being chief mechanician. Mr. Widmer has shown considerable skill as well as conscientious care and interest in the tasks set before him.

SPECIAL INVESTIGATIONS.

An investigation as to the relation between solar and terrestrial magnetic phenomena has been undertaken, in cooperation with Professor Hale, who furnished the required solar data. A comparison of the changes in solar activity and those of terrestrial magnetic activity during the period May, 1906, to January, 1909, has revealed various interesting results, the chief one being that an increase in solar activity is apparently associated with an effect on the earth's magnetization, which is equivalent to a decrease in the magnetic moment or mean intensity of magnetization. A preliminary communication was made to the American Philosophical Society last April, as also to the British Association at its Winnipeg meeting in August.

Other investigations have already been described in the sections to which they refer.

In conclusion, it gives me much pleasure to refer, as in past years, to the faithful and valuable services rendered in the office by Mr. J. A. Fleming, Magnetician in Charge.

PRESENT FRONT OF PIRENE; ONLY ROMAN WORK VISIBLE.

ARCHEOLOGY.

American School of Classical Studies at Athens. James R. Wheeler, Chairman of Managing Committee, Columbia University, New York, New York. Grant No. 548. (*a*) *Excavations at Corinth,* $1,500. (*b*) *Maintenance of a fellowship in architecture at Athens,* $1,000. (For previous reports see Year Books Nos. 4, 5, 6, and 7.) $2,500.

(*a*) *Excavations at Corinth.*—The work of excavation this year has been mainly, though not wholly, directed toward the study of the early arrangements (sixth century B.C.) for water-supply in the fountain Pirene. A sketch-plan illustrates the fountain's general features. The system consisted of four large reservoirs, 1, 2, 3, 4, from 20 to 25 meters long, 2 meters wide, and 2.50 meters high. These were cut in the hard clay, and the interior was lined with excellent cement which is to-day in almost perfect condition. The water entered each reservoir from a tunnel at the back of the system, which received its supply from two different directions, as indicated by arrows on the plan. The modern village, situated at a lower level, still receives an ample water-supply from the same sources; to-day, however, the water no longer passes through the old reservoirs, but at the side of them. The water entered each reservoir from the tunnel through two funnel-like openings (see plan, section *s–t*). Provision was evidently made for careful inspection of the tunnel, since an arrangement to set lamps at regular intervals may be observed (section *s–t*). The top of the tunnel is cut in the shape of a vault (section *s–t* and *x–y*). The water passed out of the reservoirs through five narrow openings (see plan, and section *x–y*) into the draw-basins *A, B, C.* These were approached by the water-carriers through six chambers (see plan I–VI).

The plan of this early and unique system of water-supply can now be made out, but the fountain should be excavated more completely, since no other Greek fountain of importance that has been discovered can be seen in what is practically working order. It would be very easy, after a little further excavation, to show at least one reservoir delivering the water in the ancient fashion.

Another very important source of water-supply for ancient Corinth was the fountain Glauce. This has been very carefully studied during the past year by Dr. G. W. Elderkin, secretary of the school, and careful plans of it have been drawn by Mr. W. B. Dinsmoor, Fellow in Architecture. This work is now ready for publication, and is in the hands of the editors of the Journal of Archaeology.

Besides these investigations into the water-supply of the city, some further trenches have been sunk in the Odeum and in the Theater. In the former, which dates from the second century A. D., and owes its existence to Herodes Atticus, a number of well-preserved, rock-cut seats in the lower level of the *cavea* were uncovered. In the Theater—the Greek theater which lies under the Roman and is to be dated at least as early as 300 B. C.—the excavations indicate that there was a considerably lower stage than has commonly been found in Hellenistic theaters. If further excavation should show that the structure is to be dated well back in the fourth century B. C., the fact of there having been a low stage would be of great archaeological interest.

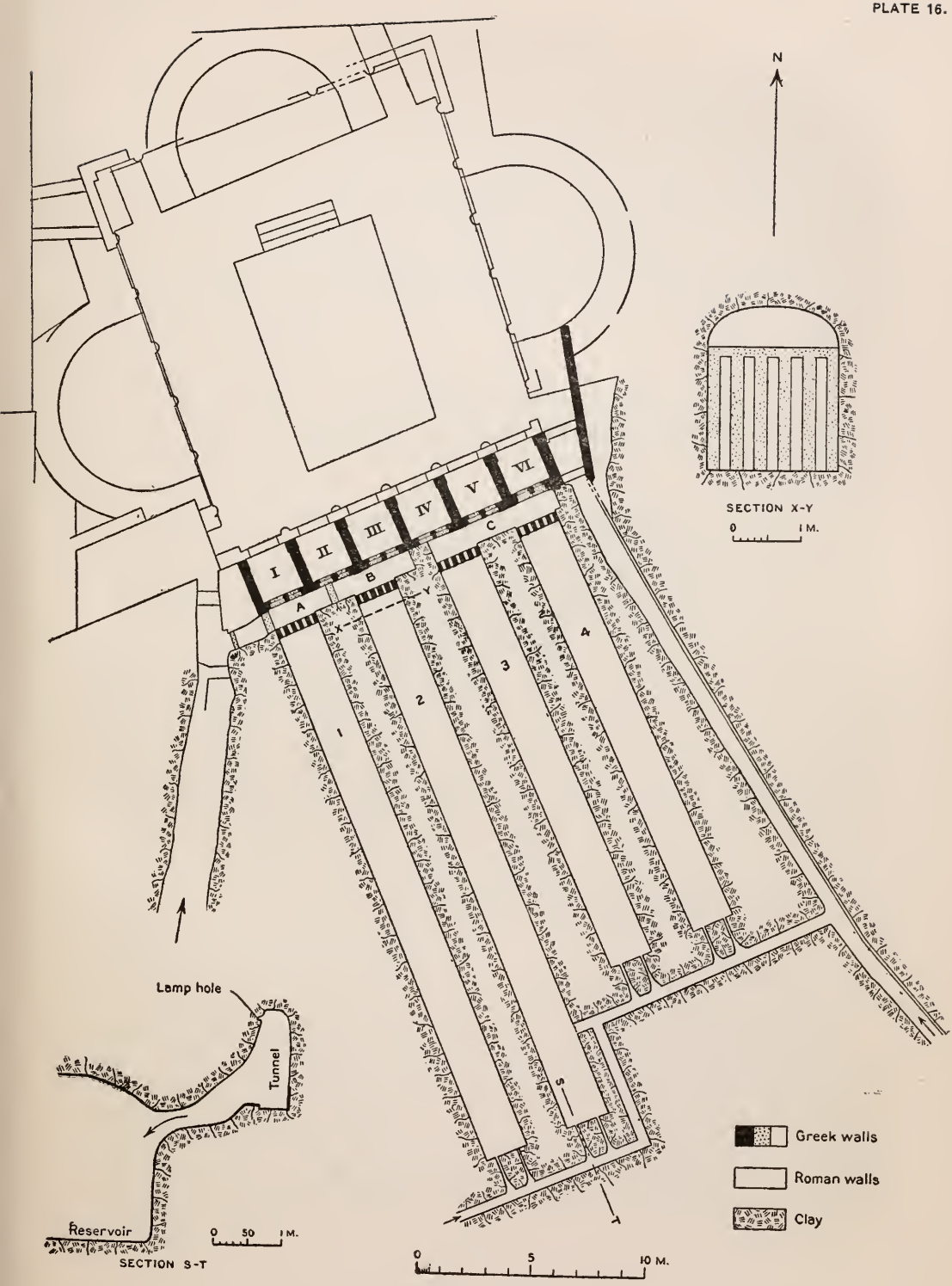
Between the Odeum and the Theater there are traces of a sanctuary, which is very probably that of Athena Chalinitis mentioned by Pausanias. The excavation is, however, only tentative at this point, and the identification of the sanctuary, which is important in Corinthian topography, is still uncertain.

(*b*) *Fellowship in Architecture.*—The appointment of Mr. William B. Dinsmoor to this fellowship has been amply justified. He has, as has already been said, spent some time in architectural study at Corinth, but his chief attention has been given to the continuation of the work already begun by Mr. Wood, his predecessor on the Propylæa at Athens. Mr. Wood's work was concerned with the wings of the building; Mr. Dinsmoor has studied the main part of it, and especially the roof construction above the actual gateway. The results of his work are nearly ready for publication and they will soon appear in the Journal of Archaeology.

So much that is new about the architecture of the Propylæa has now been discovered through the work of Mr. Wood and Mr. Dinsmoor that a new and careful publication of the building is much to be desired.

American School of Classical Studies in Rome. Andrew F. West, Chairman of Managing Committee, Princeton University, Princeton, New Jersey. Grant No. 549. *Maintenance of two research fellowships in classical archeology.* (For previous reports see Year Books Nos. 4, 5, 6, and 7.) $1,600.

Associate in Research No. 1.—Dr. Esther B. Van Deman continued for the third year her researches in Roman building construction, more especially brickwork and concrete. Besides preparing for the press her work on "The Atrium Vestæ" (in course of publication by the Carnegie Institution of Washington) and publishing a study of the "Flavian Rostra" (American Journal of Archeology, June, 1909), she examined during the year the earlier types of concrete and of wall facing, making among other things a study of the Palatine as a whole. These investigations will eventually appear in a "Handbook of Brickwork." She is to continue her work during the coming year on an independent grant from the Carnegie Institution of Washington.



PIRENE SKETCH-PLAN.

Associate in Research No. 2.—Dr. Dean P. Lockwood continued his work in "Renaissance translations from Greek into Latin." The main task for the current year was the compiling of a complete and accurate list of all such translations down to the beginning of the sixteenth century. After spending the major part of the year in the Vatican Library with the 30,000 Latin manuscripts, he made a tour of Italy examining other libraries. He expects to publish soon "A preliminary survey of the translations of the fifteenth century, with data for identifying each translation." As an immediate result an article is ready for publication dealing in general with the Renaissance Translation Movement.

Brigham, William T., Bernice Pauahi Bishop Museum, Honolulu, Hawaii. Grant No. 341. *Surveying, photographing, and describing the heiau, or ancient stone temples of the Hawaiians, in connection with a treatise on "Ancient Hawaiian Worship."* (For previous reports see Year Books Nos. 5, 6, and 7.) $2,500.

The field-work under the grant has been mainly confined to the island of Molokai, where Mr. J. F. G. Stokes, the curator of Polynesian ethnology, has spent many weeks in surveying the ruined heiau and collecting all possible information about them. The expense has been greater in proportion than on the much larger island of Hawaii, for vegetation has overgrown the ruins far more than on the other islands. Molokai is a long, narrow island lying east to west; low at the western end, but rising to a height of 4,958 feet toward the eastern, where the mountain range is deeply cut by narrow but picturesque valleys, sometimes inaccessible except from the sea, and then only in calm weather. Naturally in these secluded places old customs lingered long, and it was hoped that the memory of traditions clustering about these temples of the old faith might survive in greater strength than on the islands where foreign influence has long been potent. It was also the island where nearly half a century ago an aged priest of the old Hawaiian cult, on the still fairly preserved terraces of the principal temple on the island, the cathedral church, taught the writer more of the ancient liturgy than he has since been able to collect from all other sources.

The field-work has just terminated and the results are not worked out, but it was made plain that not much was to be learned from the modern Hawaiians, few in number and little inclined to talk of the discredited faith of their ancestors, although unwittingly giving abundant proof that its fires were merely banked, not extinguished. It was also found that what has been considered the older form of temple, a truncated pyramid, predominated; that phallic worship, by no means dead, has left extensive monuments on this island, and that the frequent wars that swept Molokai as the battle-ground of chiefs of Oahu on the northwest and Maui on the south, while working great

destruction on the fish ponds and cocoanut trees, yet spared the heiau, so far as appears.

Mr. Stokes was able to get photographs of a very curious structure of embedded stones which I measured twenty years ago, a structure not observed elsewhere in connection with Hawaiian worship, called "The place for cooking the rain." This can not be explained without illustrations.

There remain the large islands of Maui and Kauai, and the small ones of Lanai and Kahoolawe to be surveyed, which we hope to complete the next season. In the meantime certain structures on this island of Oahu will be mapped and excavated.

ASTRONOMY.

Newcomb, Simon, Washington, District of Columbia. Grant No. 550. *Investigations in mathematical astronomy, statistical methods, and economic science.* (For previous reports see Year Books Nos. 2, 3, 4, 5, 6, and 7.) $5,000.

The main object for which this grant was given has been accomplished, to wit, a precise study of the moon's mean longitude, extending over a period of some 3,000 years, in an attempt to reconcile gravitational theory with observation. Over 30 years ago the author announced that the motion of the moon was not in accord with any known gravitational theory. This result is completely confirmed by the present investigation, in which it is shown, however, that the deviations from theory are much more complicated than had been previously supposed. The predicted positions of the moon, given in the astronomical ephemerides, are in error by as much as 12 seconds of arc at the present time. Tables have already been computed, based upon the present investigation, which will reduce this error to less than 1 second.

BIBLIOGRAPHY.

Fletcher, Robert, Army Medical Museum, Washington, District of Columbia. Grant No. 578. *Preparation and publication of the Index Medicus.* (For previous reports see Year Books Nos. 2, 3, 4, 5, 6, and 7.) $12,500.

Since the last report made in relation to the Index Medicus the volume for 1908 (vol. VI) was completed and the monthly numbers for the current year are being issued. The increase of medical periodical literature throughout the world is again noticeable. The Index Medicus for 1908 forms a volume of 1,380 pages. In addition to the usual sources from which this classified medical bibliography is obtained, it is of interest to observe the increase of what may be termed "special medical congresses"—meetings of physicians from all parts of the world in some central city to discuss the

nature and prevention of some particular disease. An example may be found in the Tuberculosis Congress which met in this city last autumn. The literature of such congresses forms a valuable addition to the Index Medicus.

It may be added that twenty languages are represented in the Index Medicus; of those less generally known the titles of articles are given in English.

CHEMISTRY.

Acree, S. F., Johns Hopkins University, Baltimore, Maryland. Grant No. 555. *Continuation of study of tautomerism and catalysis.* (For previous reports see Year Books Nos. 4, 6, and 7.) $1,300.

Our work on tautomerism and catalysis has been continued with the cooperation of Dr. E. E. Reid, Carnegie Research Assistant for 1908–09, Dr. Sidney Nirdlinger, Dr. E. A. Slagle, and Dr. L. J. Desha. Some papers by Dr. Sidney Nirdlinger and Dr. L. J. Desha are awaiting publication. The five following articles have appeared during the year.

Studies in Catalysis: On the Formation of Esters from Amides and Alcohols. By S. F. Acree. (American Chemical Journal, 41, p. 457.)—In this article are discussed (1) "The rearrangement of acetylhalogenaminobenzene derivatives," (2) "The hydrolysis and esterification of amides," (3) "Salt catalysis." The new experimental and mathematical evidence obtained by Dr. J. M. Johnson and Dr. E. E. Reid strongly support the deductions drawn from our previous researches in these fields.

The Alcoholysis or Esterification of Acid Amides. By E. E. Reid. (American Chemical Journal, 41, p. 483.)—Dr. Reid's experimental results fully confirm our predictions of the course of the reactions involved in the hydrolysis and esterification of amides. As no water is formed in the esterification of amides, this reaction is regarded as more suitable for the study of catalytic esterification than the esterification of organic acids. This research is being continued.

$$CH_3CONH_2 + ROH + HCl \rightleftharpoons CH_3COOR + NH_4Cl$$

On the Theory of Indicators and the Reactions of Phthaleins and their Salts. By S. F. Acree and E. A. Slagle. (American Chemical Journal, 42, p. 115.)—In this paper are presented the results of a quantitative investigation of our theory of indicators by the use of reaction velocities and the dilatometer. The conclusions amply justify our theory that the color of the salts of phenolphthalein is due not so much to the carboxyl salts, or carboxyl and phenol salts, as assumed by others, as to another tautomeric salt, a quinone-phenolate salt analogous to certain tautomeric urazole salts, made by Acree and Nirdlinger, and to quinone-phenolates, made by Jackson and Oenslager.

$$(C_6H_4COO)C(C_6H_4ONa)_2 <\!\!\!-\!\!\!-\!\!\!-\!\!\!>$$

Colorless.

$$NaOOCC_6H_4C(:C_6H_4:O)(C_6H_4ONa) <\!\!\!-\!\!\!-\!\!\!-\!\!\!>$$

Colored.

$$NaOOCC_6H_4C(:C_6H_4:O)(C_6H_4ONa)$$

Deeply colored.

An Electrically-Controlled Gas Regulator. By E. E. Reid. (American Chemical Journal, 41, p. 148.)—This article describes a very efficient iron gas regulator, which is cheap and simple in construction.

An Apparatus for the Purification of Mercury. By L. Junius Desha. (American Chemical Journal, 41, p. 152.)—Mercury is automatically forced in fine streams through dilute nitric acid about 150 times a day, and is electrolyzed at the same time. This procedure removes with ease practically all of the metallic impurities from the mercury, which is then distilled. The apparatus is very simple and runs day and night without attention.

Bancroft, Wilder D., Cornell University, Ithaca, New York. Grant No. 556. *Systematic study of alloys.* (For previous reports see Year Books Nos. 2, 3, 4, 5, 6, and 7.) $1,500.

The iron-carbon alloys have been annealed in a vacuum until equilibrium was reached, and have then been examined under the microscope. The results show that we are dealing with a reversible equilibrium and that the Upton diagram is substantially correct. We are now running heating and cooling curves in order to determine the different inversion temperatures. We hope also to show the existence of δ iron and thus to confirm the work of Ball, of Osmond, and of Pierre Curie.

Tensile-strength tests have been made on the zinc-aluminum alloys and we are now investigating the cause of the disintegration of some of these alloys.

The diagram for the zinc-antimony alloys, as published by Mönkemeyer some years ago, contained a line which was theoretically impossible. This difficulty has now been cleared up. It was due in large part to hysteresis phenomena during cooling. Errors of 70° or even 100° in the determination of inversion temperatures may occur when cooling curves alone are taken. This case illustrates in a striking manner the possibility of error due to supercooling. We have also determined the diagrams for several other binary alloys containing zinc as one component. A preliminary account of this work will appear in the Journal of Physical Chemistry for November.

Baxter, Gregory P., Harvard University, Cambridge, Massachusetts. Grant No. 579. *Determination of atomic weights.* (For previous reports see Year Books Nos. 3, 4, 5, 6, and 7.) $1,000.

With the assistance of grant 579 the following researches were carried on under Professor Baxter's direction:

Since the atomic weights of silver and iodine referred to oxygen calculated from the ratio of silver to iodine pentoxide (recently published, see Year Book No. 7, pp. 189–192) are dependent upon a knowledge of the ratio of the atomic weights of silver and iodine, and since a given percentage error in the latter ratio is multiplied by three in the atomic weights of silver and iodine, it is highly desirable to reinvestigate the ratio of silver to iodine. Such an investigation is now in progress.

The analysis of tri-silver phosphate, begun some time ago by Dr. Grinnell Jones (see Year Book No. 6, p. 184), has been completed. Four different samples of tri-silver phosphate were precipitated under as widely different conditions as possible. Sample O was prepared by adding a dilute solution of silver nitrate to a dilute solution of di-sodium phosphate; sample N by neutralizing the mother-liquor of sample O with ammonia. Sample P resulted from the addition of a solution of sodium ammonium hydrogen phosphate to a solution of silver nitrate, and sample R from the addition of sodium di-ammonium phosphate to silver nitrate. The different samples were thoroughly washed with water and dried. Portions of the phosphate were heated in a current of pure dry air for several hours at 400° C.; then, after being weighed, they were analyzed by solution in nitric acid and precipitation with hydrobromic acid.

A slight amount of residue insoluble in dilute nitric acid was found to have essentially the same proportion of silver as the phosphate itself. This residue was always dissolved in more concentrated nitric acid before the precipitation of the silver bromide; hence no correction for the residue is necessary.

Since silver phosphate can be fused only with the greatest difficulty, the determination of the water in the dried salt was accomplished by dissolving the phosphate, after being dried at 400°, in fused silver chloride and collecting the water set free in a weighed phosphorus pentoxide tube. The water actually found in the salt was less than 0.0005 per cent, a negligible quantity.

The density of the salt was found by displacement of toluol in two experiments to be 6.37.

By determining the gain in weight when air was admitted to an exhausted tube containing a weighed amount of silver phosphate, it was shown that the salt does not adsorb appreciable amounts of air.

The final results of the research are as follows:

Sample.	No. of analyses.	Ratio, $3AgBr : Ag_3PO_4$.
O	2	1.34559
N	3	1.34564
P	2	1.34565
R	2	1.34558
Average		1.34562

Although prepared under conditions differing considerably in basicity and acidity, the different samples evidently are of essentially the same composition and may reasonably be assumed to represent tri-silver phosphate free from basic or acid impurities. If the atomic weight of silver is assumed to be 107.88 referred to oxygen 16.000, the atomic weight of phosphorus calculated from the above ratio is 31.04. The results of this investigation will shortly be published.

The analysis of phosphorus tri-bromide, begun last year by Mr. A. C. Boylston (see Year Book No. 7, p. 191), has been continued by Dr. C. J. Moore, but no final results have been obtained as yet.

The purification and analysis of neodymium chloride have been continued by Mr. H. C. Chapin. The material for analysis was fractionally crystallized first as double ammonium nitrate from dilute nitric acid, then as nitrate from concentrated nitric acid, the extreme mother-liquor and crystal-fractions being occasionally rejected. The series of fractions in each crystallization numbered about 20. 103 sets of crystallizations as double nitrate and then 67 as nitrate from nitric acid were carried out. Most of the impurities which accumulate in the crystals in the first process pass into the mother-liquors in the second. In this way it was hoped to free the neodymium from closely related elements more completely than is possible by crystallization as any single compound.

Of the final series of fractions the 10 nearest the crystal-end from their absorption spectrum seemed to be pure, those nearer the opposite end of the series containing small, gradually increasing amounts of praseodymium. From this final series of fractions several were selected for analysis, adjacent fractions being combined in order to give sufficient material to handle. The extreme crystal fraction is numbered 1. In addition to these samples two fractions, *A* and *B*, were removed at different times during the crystallization as double nitrate. These latter fractions were found to contain traces of praseodymium, which were determined spectrographically by comparison with known amounts of praseodymium.

The different samples were carefully converted to chloride and were dried for analysis in a current of hydrochloric-acid gas at about 350°. Fusion of

the salt before weighing was not considered advisable on account of the high fusing point of neodymium chloride and the consequent danger of contamination through attacking of the glass tube by the hydrochloric acid gas. In each weighed portion of chloride the chlorine was determined either by titration against weighed equivalent amounts of silver or by weighing the silver chloride produced. The results of the analyses follow, calculated on the basis of silver 107.88.

Sample.	Per cent of praseodymium.	Atomic weight of neodymium.	Atomic weight of neodymium corrected for praseodymium.
A	0.2	144.272	144.280
B	0.15	144.285	144.291
1 + 2	0.0	144.295	144.295
4 + 5 + 6	0.0	144.272	144.272
10 + 11	0.0	144.286	144.280
14 + 15	0.1	144.271	144.275
Average.	.....	144.279	144.282

These results are subject to two uncertainties: First, the neodymium chloride, since it was not fused, may have contained moisture. Since, however, the salt was dried wholly by efflorescence, without melting, it is probable—from experience with other salts—that only traces of moisture were retained. Preliminary experiments to confirm this conclusion by determining the loss in weight during fusion of the neodymium chloride were on the whole satisfactory. The second uncertainty is in the vacuum correction of the neodymium chloride. Time has been lacking to redetermine the specific gravity of the salt. In the calculations for the table of results Matignon's value of 4.20 is used.

The close agreement of the results obtained from so wide a range of material indicates that the different samples were essentially identical and reasonably pure. The final result agrees very well with von Welsbach's most recent determination, 144.5, and with that chosen by the International Committee on Atomic Weights, 144.3.

The atomic weight of iron was investigated by Mr. Victor Cobb. Very pure metallic iron was converted to ferrous bromide by solution in hydrobromic acid, and the salt was several times recrystallized from hydrobromic-acid solution. The crystals were dehydrated and fused in a weighed quartz boat in a current of nitrogen and hydrobromic-acid gases. It was found impossible to use a platinum boat for the purpose, since, owing to partial dissociation of the ferrous bromide vapor, an iron-platinum alloy was formed in considerable quantity. Finally, the salt was dissolved in slightly acidulated water, and after careful oxidation with a slight deficiency of potassium

dichromate the solution was titrated against a weighed equivalent amount of silver and then the silver bromide was collected and weighed.

Preliminary experiments indicate the value 55.85 for the atomic weight of iron, if silver is assumed to have the value 107.88. The result is essentially identical with that previously obtained by Baxter with ferrous bromide which had been sublimed in porcelain tubes, and which contained a small quantity of alkali extracted from the tubes. This investigation will be continued with several samples of iron, including meteoric iron.

Mr. W. A. Worsham continued the investigation upon the atomic weight of lead (see Year Book No. 6, p. 185). At first the attempt was made to synthesize lead sulphate quantitatively. This salt, when precipitated from even very dilute solutions, occludes soluble lead salts to a very marked degree. Attempts to eliminate the occluded salts by fusion of the lead sulphate in a current of sulphur trioxide failed because of the dissociation of the trioxide at temperatures above the fusing point of the salt. Hence lead sulphate was finally rejected as entirely unsuited for exact analysis. Lead bromide was next selected for investigation. Some difficulty was experienced in obtaining salt free from insoluble basic impurities. This was finally accomplished by fusing, in a current of nitrogen and hydrobromic-acid gases, salt which had been recrystallized from hydrobromic-acid solution. No analytical results have yet been obtained.

Jones, Harry C., Johns Hopkins University, Baltimore, Maryland. Grant No. 557. *Investigations of the absorption spectra of solutions.* (For previous reports see Year Books Nos. 2, 3, 4, 5, 6, and 7.) $1,200.

The work during the present year has had to do with three problems: (1) The study of the absorption spectra of certain potassium salts containing colored anions; (2) the absorption spectra of uranyl salts; (3) the effect of temperature on the absorption spectra of salts of a number of metals.

The work with potassium salts included potassium ferrocyanide, potassium ferricyanide, potassium chromate, and potassium dichromate. The apparatus used in this part of the work is essentially the same as that employed by Jones and Anderson.* Light from the arc or Nernst filament was passed through the solution in a glass vessel closed at both ends by plates of quartz. The vessel is made by inserting one glass tube into another through a cork, and thus the depth of the solution through which the light is allowed to pass could easily be regulated. The work with the potassium salts has had to do especially with testing Beer's law for these solutions. If Beer's law holds for the absorption spectra of a given substance, then if we increase the dilution of the solution and at the same time keep the amount of colored matter in the path of the beam of light constant, the absorption bands should not

* Publication No. 110, Carnegie Institution of Washington.

change either in width or position. In a word, it is only necessary to keep the product of concentration and depth of cell constant. It was found that Beer's law holds for all four of the above-named potassium compounds. This would be expected, since no one of these compounds crystallizes with any large amount of water and is therefore not largely hydrated in solution.

The following uranyl salts were brought within the scope of this work: chloride, bromide, nitrate, sulphate, and acetate. The absorption spectra of all of these salts in aqueous solution were studied; also the chloride and nitrate in solutions in methyl and ethyl alcohols. Beer's law was found to hold for all dilute solutions of these salts. There were deviations from Beer's law in the more concentrated solutions in water of uranyl nitrate and sulphate; these solutions showing *greater absorption* than would be expected if Beer's law holds. Uranyl acetate, on the other hand, showed in concentrated solutions less absorption than would be expected from this law. This is the only salt thus far studied which deviated in this direction from the law.

This same salt in methyl alcohol shows the same kind of a deviation from Beer's law, but not to the same extent.

The absorption spectra of uranyl salts were found to show 12 bands in the blue-violet portion of the spectrum; 2 of these having never been observed before. Several new and very fine bands were found in the aqueous solutions of uranyl chloride; these bands disappear when calcium or aluminium chloride is added to the aqueous solution; they do not appear at all in the alcoholic solutions and may be "water" bands.

Some interesting results were obtained in reference to the positions of the uranyl bands. The uranyl nitrate bands are all shifted towards the violet with respect to the bands of the other uranyl salts. The uranyl nitrate bands in methyl alcohol and ethyl alcohol are shifted towards the red.

The addition of calcium chloride or aluminium chloride to aqueous solutions of uranyl chloride shifts the bands towards the red. The addition of calcium chloride to a methyl alcohol solution of uranyl chloride does not produce any shift in the bands. Hydration thus undoubtedly has much to do with the shift of these bands.

As will be seen, rise in temperature shifts the bands of uranyl chloride and uranyl sulphate towards the red.

The absorption spectra of uranyl chloride in water to which aluminium chloride is added is practically the same as the absorption spectra of uranyl chloride in ethyl alcohol.

The absorption spectra of uranyl chloride in methyl alcohol shows that the bands are shifted toward the red with respect to the bands in the aqueous solution. When calcium chloride is added to the methyl alcohol solution of uranyl chloride the spectrum is very similar to that of uranyl chloride in ethyl alcohol.

We thus see that by adding aluminium chloride to an aqueous solution of uranyl chloride, or by adding calcium chloride to a methyl alcohol solution, we get approximately the same absorption spectrum as in the ethyl alcohol solutions of uranyl chloride.

It would be expected that raising the temperature of an aqueous solution of uranyl nitrate would cause the bands to be shifted toward the red, in the same way as the bands of uranyl chloride and uranyl sulphate are shifted with rise in temperature; but such is not the case.

On the whole, the problem of the shifting of the uranyl bands is a very complex one, and much more work remains to be done upon it.

The absorption spectra of uranous chloride and uranous sulphate have also been photographed. It was found that the absorption spectrum of uranous chloride in water was fundamentally different from that in methyl alcohol.

The absorption spectra of neodymium chloride in glycerol and in glycerol and water have been obtained. The spectrum of this salt in pure glycerol is very different from that in pure water. As water is added to the glycerol solution the "glycerol" bands disappear gradually and the "water" bands come out in their stead.

From the above effect of the nature of the solvent upon the absorption spectra of uranyl, uranous, and neodymium salts, it is concluded that *solvates* are formed which are, of course, different for every solvent; and that these solvates modify the vibrations of the electrons within the atoms, ions, or molecules.

A large part of the year's work has been spent upon the *effect of temperature* on the absorption spectra of solutions. The apparatus used was designed by Dr. John A. Anderson. Two right-angled quartz prisms were each backed along the hypotenuse by a glass plate fastened in position by cement. This inclosed an air-space which gave total reflection. The two prisms were mounted in a gold-plated brass frame, and dipped into a glass trough which contained the solution to be investigated. One prism could be moved horizontally, thus making it possible to work with a layer of the solution ranging from 0 mm. to 200 mm.

Light from the Nernst filament or spark fell normally upon one of the prisms, was totally reflected by the air-film, passed through the solution, entered the second prism, was totally reflected by the air-film here, and left the second prism in a vertical direction. The light was received upon the speculum concave mirror of the spectroscope, and then reflected into the slit of the spectroscope.

Photographic films were furnished us by Wrattan and Wainwright which were sensitive from λ 2,100 to λ 7,500. The temperatures used were 0°, 15°, 30°, 45°, 60°, 75°, and 85°; and two different concentrations of each salt

were studied. The absorption spectra of the different concentrations of cobalt chloride, cobalt nitrate, cobalt acetate, cobalt sulphocyanate, cobalt sulphate, nickel sulphate, nickel acetate, nickel chloride, chromium nitrate, chromium chloride, chromium sulphate, chromium acetate, potassium chromium sulphate, copper nitrate, copper bromide, uranyl sulphate, uranyl nitrate, uranyl chloride, uranyl acetate, uranous chloride, the chloride, bromide and nitrate of neodymium, the chloride and nitrate of praeseodymium, and erbium chloride have been investigated between 0° and 90°. Various mixtures of the above chlorides with calcium and aluminium chlorides have also been studied.

For every solution investigated of a single salt in a single solvent, it was found that the change in the absorption spectra with rise in temperature was much greater for the more concentrated solutions, and as the solutions became more and more dilute the effect of rise in temperature became gradually less and less.

The temperature effect, however, in the case of a dilute solution of one salt in a concentrated solution of another salt may be very great. An example of this is a dilute solution of cobalt chloride in a concentrated solution of aluminium chloride. To summarize briefly, the effect of rise in temperature on absorption spectra:

(1) Of the colored solutions thus far investigated practically all show increased absorption with rise in temperature.

(2) Many broad bands such as those of cobalt, chromium, and a few of the wide bands of concentrated solutions of the neodymium salts widen unsymmetrically, and this widening is invariably the greatest on the long wave-length edge of the bands.

(3) Some of the finer bands are shifted to the red with rise in temperature, without much or any widening of the bands. Good examples of this kind of shift are aqueous solutions of uranyl chloride and uranyl sulphate.

(4) The addition of calcium chloride or aluminium chloride to chromium chloride causes the chromium bands to widen entirely on their red edges, and may even cause the bands to narrow on their short wave-length edges.

(5) For aqueous solutions of salts of neodymium and erbium no shift of the bands was noticed with rise in temperature. The addition of calcium chloride to the solution of neodymium chloride caused the neodymium bands to shift to the red with rise in temperature, and also produced a weakening of some of the bands. The presence of aluminium chloride and calcium chloride seems to play a very important rôle in the effect of temperature on the absorbing power of solutions.

Morse, H. N., Johns Hopkins University, Baltimore, Maryland. Grant No. 569. *Study of the measurement of the osmotic pressure of solutions.* (For previous reports see Year Books Nos. 2, 3, 4, 5, 6, and 7.) $1,800.

The work of the past year has had for its object the determination, with all possible accuracy, of the relation of osmotic pressure to temperature. To this end, our efforts have been primarily in the direction of improvements in method, though many satisfactory measurements of pressure have been made.

The improvements in method to which attention has been given may be classified under the following heads: "Cells," "Membranes," "Manometers," and "Devices for the regulation of temperature." A high degree of perfection in all of these is essential to any authoritative determination of the temperature coefficient of osmotic pressure.

(1) *Cells.*—The test of excellence in a cell is its ability to maintain undiminished the concentration of the inclosed solution. So long as the solution suffers dilution during a measurement it is impossible, as has been explained elsewhere, to ascertain precisely its osmotic pressure. But the construction of cells which exclude all of the numerous sources of possible dilution has been, from the first, a problem of the greatest difficulty, and one whose solution has required ten years of continuous effort. During the past year the last of our difficulties in this direction has been overcome, and none of the solutions whose pressure has been measured during the latter part of the year 1908–09 has shown any loss in concentration which could be detected by the polariscope. The improvements in cells which eliminated the major portion of the dilution of the solutions were described in a paper which appeared in September, 1908 (American Chemical Journal, XL, 266). The subsequent ones, which finally suppressed all loss in concentration, will be described in a later communication.

(2) *The membranes.*—The suppression of all dilution, through improvements in cell construction, was a final demonstration of the truly semipermeable character of the membrane, but it was observed, as the measurements of pressure, from various causes, became more precise, that, on some occasions, notwithstanding the cell contents showed no loss in concentration, the solutions failed, by small amounts, to develop the highest pressures which had been observed at other times. These discrepancies, which were of little importance as long as the sources of error in the method were numerous and large, became a matter for serious attention during the past year. The membrane can not be studied directly, and any conclusions regarding the cause or causes of its misconduct on any occasion must be based upon what is known of the conditions under which it was formed; hence the definite location of a defect, or of the cause of imperfect action, is usually a matter of considerable trouble in the case of osmotic membranes. Nevertheless, we were able

to find the probable cause of the peculiar conduct mentioned above, or at least to discover a course of procedure in the treatment of the membranes which obviated the difficulty.

(3) *Manometers.*—Numerous improvements in the manometric portion of the work were described in a paper which appeared in October, 1908 (American Chemical Journal, XL, 325); but the obvious necessity of developing this branch of the investigation to the highest possible state of perfection before attempting to settle finally the temperature coefficient of osmotic pressure, led us into a protracted and careful examination of the manometers which are employed in the measurements. In the first place, there was devised and brought into successful working condition an observation chamber for the manometers, which could be maintained automatically for any required length of time, at any desired constant temperature, and in which the instruments could, at a constant temperature, be calibrated and compared one with another and with a standard manometer, under varying pressures. The manometers were opened and recalibrated by different methods. They were then filled with purified nitrogen, and the volumes of the gas were determined under ten different known pressures which corresponded with the mean pressures of the ten concentrations of solution which we are accustomed to measure. Finally, the manometers were compared, one with another and each with the standard instrument, under the same ten different pressures. The work of the past year in this direction was elaborate and thorough, and consumed over eight months of time.

(4) *The Regulation of Temperature.*—The exact regulation of temperature for long periods is of fundamental importance in the measurement of osmotic pressure, and we described, in a paper which appeared in February, 1909 (American Chemical Journal, XLI, 92), the automatic system developed by us, during the past ten years, for this purpose. Other improvements have since been introduced until, at the present time, the maximum fluctuation in the temperature of the large baths during a series of measurements does not exceed 0.02°, and the difference between the temperature of the solutions and that of the manometers is too small to introduce sensible errors.

Five series of measurements of the osmotic pressure of cane-sugar solutions have been carried out during the year, each series consisting of duplicate or triplicate determinations on ten concentrations of solution.

Two of the five series, one at 25° and the other at 20°, were completed before some of the latest and most important improvements in method had been introduced, and they can not, therefore, be considered as having quite equal weight with the last three series of measurements, which were carried out under more favorable conditions. An account of the work at 25° appeared in January, 1909 (American Chemical Journal, XLI, 1), and of that at 20° in April, 1909 (American Chemical Journal, XLI, 257).

Series 3, 4, and 5, at 0°, 5°, and 10°, were executed under the best conditions which we are able at present to command. There was not, in any case, a sensible loss of concentration while the solutions were in the cells; the maximum variation in the temperature of the bath during any series of measurements did not exceed 0.02°. The *thermometer effects* were therefore small and every possible precaution was taken to insure the correctness of the manometers and of the readings.

In order to prepare uniform material for these and later measurements of pressure, 75 kilograms of the purest obtainable rock-candy were purified by three successive precipitations from aqueous solution with ethyl alcohol, each precipitation being followed by a washing of the crystals upon the filter with both ethyl and methyl alcohols. The Bureau of Standards at Washington has kindly undertaken for us a polariscopic examination of the original material and of the products of the different recrystallizations.

The results of series 3, 4, and 5, which have not been published elsewhere, are given below in the form of ratios of osmotic to calculated gas pressures. It will be seen, on comparing the figures for any one concentration at different temperatures, that the ratios are practically identical, differing from the mean value at most by only 2 units in the third decimal place, showing that the temperature increment of osmotic pressure from 0° to 10° is identical with that of gases; in other words, that the osmotic pressure of cane-sugar solutions, within this range of temperatures, obeys the law of Gay-Lussac for gases.

Two blank spaces occur in the table, owing to the fact that the work in the regions in question is still incomplete.

Ratios of osmotic to calculated gas pressures.

Weight normal concentration.	Temperature.			Mean ratio.
	0.0°	5.0°	10.0°	
0.1	.....	1.082	1.082	1.082
0.2	1.061	1.063	1.061	1.062
0.3	1.061	1.059	.....	1.060
0.4	1.061	1.061	1.060	1.060
0.5	1.068	1.067	1.066	1.067
0.6	1.076	1.074	1.072	1.074
0.7	1.084	1.084	1.083	1.084
0.8	1.094	1.094	1.093	1.094
0.9	1.104	1.101	1.102	1.102
1.0	1.115	1.115	1.114	1.115

In the work here reported, the writer has had the continuous assistance of Drs. W. W. Holland and B. B. Turner, and of Messrs. E. E. Gill and E. G. Zies. Messrs. G. Cash, W. M. Clark, and C. N. Meyers have also rendered valuable service.

Noyes, Arthur A., Massachusetts Institute of Technology, Boston, Massachusetts. Grant No. 576. *Researches upon the physical properties of aqueous solutions in relation to the ionic theory.* (For previous reports see Year Books Nos. 2, 3, 4, 5, 6, and 7.) $3,000.

During the past year the researches described in previous reports have been continued, especially in the direction of perfecting the method and apparatus so as to enable the specific volume, compressibility, and vapor-pressure of water to be determined between the critical temperature and 306°, the highest point to which the previous measurements had been carried. The same apparatus will also be used with some modifications for measurements of the electrical conductivity of solutions at these high temperatures. This work, which has been carried out with the assistance of Mr. Roy D. Mailey, will be continued during the coming year.

Because of its important bearing on the general purpose of these researches, which is to so develop the ionic theory as to account for the striking anomalies which solutions of strong electrolytes exhibit, a new line of work has been undertaken during the past year with the aid of Dr. William C. Bray. This consists in a careful study of the effect of salts on the solubilities of one another, in order to determine what modifications the well-known principles of solubility-effect applicable to dilute solutions require in cases where the salts exist to a considerable extent in the un-ionized state. The effects of potassium chloride and sulphate on the solubility of potassium perchlorate, and of thallium nitrate, thallium chlorate, and sodium sulphate on that of thallium sulphate have been studied in this way. The results show that the concentration of the un-ionized part of the salt with which the solution is saturated is much less in solutions that contain another salt with a common ion than in pure water, and that the product of the concentration of the ions of the salt saturating the solution is somewhat greater in the former case than in the latter, while these two quantities would remain constant provided the substances behaved normally. The deviations in the case of salts of the tri-ionic type are especially striking, and a fuller study of them gives promise of throwing much light on the cause of the anomalies.

During the past year an article has been published (Jour. Am. Chem. Soc., 31, 987–1010) upon the "Conductivity and Ionization of Polyionic Salts," describing the work previously completed with the aid of Dr. John Johnston and described in an earlier report. A paper on the solubility of certain difficultly soluble salts at high temperatures is also about to be published.

Richards, Theodore W., Harvard University, Cambridge, Massachusetts. Grants Nos. 524 and 570. *Extended investigations of precise values of atomic weights and other physico-chemical constants; and a study of volume and energy relative to material in relation to the new hypothesis of compressible atoms.* (For previous reports see Year Books Nos. 2, 3, 4, 5, 6, and 7.) Each grant, $2,500.

During the academic year 1908–09 portions of these grants were used in the completion of five researches and the beginning of several others, as follows:

I. *The Revision of the Atomic Weights of Lithium, Chlorine, and Silver:*

With the help of Dr. H. H. Willard, upon leave of absence from the University of Michigan, a comprehensive research was continued and essentially completed, involving several important atomic weights. The object of this research was to secure a better comparison than has ever yet been made between the atomic weights of oxygen and silver. The need of the comparison is due to the fact that whereas oxygen is the standard of atomic weights, most elements are, as a matter of fact, referred either directly or indirectly to silver. The first step in this research consisted in a study of the properties of all the compounds of oxygen which might be used for the purpose, and for many reasons lithium perchlorate was chosen as the most suitable substance for investigation. The precise quantitative study of this substance involved the evaluation of the atomic weight of lithium as well as of all the other elements concerned, and accordingly this determination formed the first step in the work. The methods used were so similar to those discussed in Publications 28 and 69 as to render repetition unnecessary. It was proved beyond doubt that Stas's value for the atomic weight of lithium was almost 1 per cent in error and that the true value is not far from 6.94. Lithium chloride was then changed into lithium perchlorate in suitable quartz apparatus with every quantitative refinement. Because the original salt had already been referred to metallic silver, it is clear that this determination gives at once the ratio

$$Ag : 4(O)$$

If, as is probable, the perchlorate fused at 300° is essentially free from water, the atomic weight of silver is shown by these results to be not far from 107.87—an interesting and important confirmation of other recent work upon this subject. The question as to whether or not a trace of water remains in the perchlorate will be answered in the near future.

II. *Adiabatic Determination of the Heats of Solution of Metals in Acids:*

With the help of Dr. L. L. Burgess the heat evolved by the action of the more electro-positive among the heavy metals was studied with great care, the object being to secure precise data for thermochemical and thermody-

namic computations. The new method of adiabatic calorimetry recently developed at Harvard is especially suitable for cases of protracted reaction of this kind. The study of these reactions led to the discovery of several minor calorimetric errors which had vitiated most of the earlier determinations; the sum of these errors amounted in some cases to a considerable quantity. Especially it was shown that more thorough stirring than is usually practiced is absolutely essential for great accuracy. The heats of solution of zinc, iron, aluminum, cadmium, and magnesium were determined with great accuracy, hydrochloric acid being used as a solvent. In order that all the results might be calculated to the same standard, the heats of dilution of the hydrochloric acid of the residual mixtures in the calorimeter were in each case determined and the data all finally calculated so as to represent the heat of solution of 1 gram-atom of the metal in acid with 200 gram-molecules of water. Moreover, the heat of precipitation of silver from a solution of silver perchlorate by cadmium was determined in order to serve as a basis for the heat of formation of silver salts.

III. *Heats of Combustion of Certain Liquid Hydrocarbons:*

In the further prosecution of the revision of thermochemical data, the heats of combustion of a number of octanes and zylenes were carried out with unusual care. The object in choosing these substances was to endeavor to trace the effect of constitution or arrangement upon the heats of formation of isomeric substances and thus to obtain more definite ideas of the relation of total energy change to structure. The hydrocarbons were prepared in a state of great purity by Dr. Lathan Clarke according to methods worked out several years ago for this purpose. Octanes in particular were chosen because the molecule is large enough to admit of considerable variety in the isomeric compounds, but not so large as to confuse the relationships. Simplicity in interpretation is also gained by having only two elements present. In the execution of this work the adiabatic method of calorimetry already mentioned in the previous paragraph was applied with equal success, and in general the precautions used in previous work of this kind were adopted throughout.

Further investigation of the burning of these very volatile compounds showed that special pains must be taken with regard to the form of the containing vessel and the details of manipulation in order to insure complete combustion. The volatile liquids were sealed in flexible glass bulbs and ignited by means of small weighed quantities of sugar in such a way that the combustion was in every case complete. The results showed very satisfactory agreement among themselves. The details may be omitted here; but it is interesting to note that the heats of combustion of the liquid isomers were very nearly the same in every case. The maximum deviation amounted

to only one-third of 1 per cent. This indicates the interesting fact that the heat of formation of the vapor from the elements is greater in those cases where the heat of condensation is less, and *vice versa.* In the case of the zylenes also the maximum deviation was only about 0.3 per cent, ortho- and meta-zylene giving exactly the same values and para-zylene slightly less. Stohmann found no difference among the three; but he was much dissatisfied with his determinations. As ortho-zylene boils at a temperature considerably above meta-zylene and its heat of vaporization must therefore be greater, it is apparent here also that the vapor which possesses the greater heat of condensation possesses the less heat of formation. In other words, the combining energy which is not used up in chemical combination seems to be available for cohesive action. One is inclined to infer that chemical affinity and cohesion are merely different manifestations of the same forces. This investigation will be continued in the near future and the effort will be made to obtain as much light as possible upon the energy relations of these closely related compounds.

IV. *The Heat of Neutralization of Strong Acids and Strong Bases:*

Another highly important branch of thermochemistry concerns the phenomenon of heat of neutralization. In view of the comparatively crude methods which have been used by most of the experimenters upon this subject, revision seemed to be desirable, and the problem was undertaken with the help of Dr. A. W. Rowe. The investigation is, as a matter of fact, by no means as simple as it might seem. In the first place, the specific heats of the solutions upon which the whole calculation depends must first be determined with as great accuracy as the heat evolved during chemical reaction, and the methods heretofore used for this purpose are by no means satisfactory. The first step of the research was therefore the development of an accurate and convenient method for determining the specific heats of solutions, already mentioned in the last report. Further investigation improved somewhat some of the details of this process, so that no great difficulty is now in the way of determining specific heats within one-thirtieth of 1 per cent.

In studying the heat of neutralization itself two methods were adopted. In the first place, concentrated alkali was allowed to mix with dilute acid, and in separate determinations the heats of dilution of the various solutions to the usual standard—1 molecule of dissolved substance to 200 of water—were found and applied to the results. In another set of determinations the dilute acid and dilute alkali of this standard strength were caused to mix in two concentric platinum cans, the inner one having contained in the first place one of the liquids and the outer annular space having contained the other. Great care is needed in effecting the mixture in order to be sure that the heat is evenly distributed throughout the mass, and special precautions were

taken in order to attain this object at every stage of the process. Concordant results have been obtained with hydrochloric acid and sodium hydroxide by means of these two entirely different methods, the result indicating that the usually accepted values for the heat of neutralization are decidedly too low. The investigation is to be continued next winter, and a fuller report may be reserved until a series of figures with different acids and alkalies have been obtained.

V. *The Compressibilities of Certain Isomeric Hydrocarbons:*

In continuation of the work upon compressibility, the beginning of which is described in Publication No. 7 and continued in Publication No. 76, and in connection with the work above summarized concerning the heats of combustion of octanes and xylenes, the compressibilities of these substances at various temperatures was investigated in detail with the help of Prof. C. L. Speyers, formerly of Rutgers College. The effort was made to attain greater accuracy than ever before in this work, and with the help of Dr. P. W. Bridgman, of the Department of Physics of Harvard University, the standard of pressure was verified to a degree of precision far exceeding anything which has hitherto been obtained. It is satisfactory to note, however, that the standard used in the previous work was not sufficiently in error to influence essentially any of the results there recorded. Many slight improvements in manipulation were introduced and the method for determining compressibility was found to give satisfaction as before.

Five octanes were investigated with great care. It was found that their compressibilities varied over a much wider limit than their heats of combustion, being comparable to the variations in the boiling-point. In general, as had been predicted upon the basis of the theory of compressible atoms, the isomers with higher boiling-points possess lower compressibility; but there are interesting minor variations in these relationships which deserve further investigation.

Ortho- and meta-xylene and ethyl benzene also were investigated, and it was found here also that the substance with the greatest compressibility, namely meta-xylene, possesses the least density. This investigation also will be continued during the coming winter and a full report will be reserved for a future date.

In addition to these five researches which have produced results already worthy of publication even if nothing more should be done upon them, several other researches have been begun or continued, although they have not yet reached as definite a stage. Chief among these is perhaps an investigation of the compressibility of ice. Study of the literature of compressibility has failed to reveal any data upon this subject. Nevertheless, it is one of great interest, not only because of the part played by ice in remodeling the

surface of the earth, but also because of the theoretical importance of the volume changes exhibited by this remarkable substance. Accordingly, the careful study of the compressibility of ice was undertaken, with the help of Professor Speyers. No great difficulty was found in executing the determination at —7° C., by means of a method similar to that described in Publication No. 7, but more results are needed before a final statement of the value can be given.

Another important unfinished investigation is the continuation of the study of ammonium bromide, conducted with the assistance of Messrs. F. B. Coffin and G. S. Tilley. It was found that ammonium bromide has a decided tendency to occlude ammonia and that the preparation of that substance in a typical state is by no means easy. Until more precise means of assuring definiteness of composition has been obtained, the report of the final results can have little significance. The careful alkalimetric study of the solutions of the salt with the help of the theory of electrolytic dissociation, taking due account of hydrolysis, promises to solve the difficulty when more accurate determinations of conductivities and more precise study of indicators has been completed; and the work will be prosecuted in these directions. Other work concerning atomic weights, as well as heats of reaction and compressibilities, will be undertaken also.

A number of the previous investigations have appeared in print during the past year, at least in part. Reference to these publications will be found in the Bibliography.

GEOLOGY.

Chamberlin, Thomas Chrowder, University of Chicago, Chicago, Illinois. Grant No. 571. *Inquiry into the fundamental problems of geology.* (For previous reports see Year Books Nos. 2, 3, 4, 5, 6, and 7.) $4,000.

During the institutional year ending October 31, 1909, eight papers were finished and published. Six of these constituted a correlated group relating to those phases of the tidal problem which have cosmogonic and geologic bearings, as follows:

The former rates of the earth's rotation and their bearings on its deformation, by T. C. Chamberlin.
The rotation period of a heterogeneous spheroid, by Charles S. Slichter.
On the loss of energy by friction of the tides, by William D. MacMillan.
On certain relations among the possible changes in the motions of mutually attracting spheres when disturbed by tidal interactions, by F. R. Moulton.
Notes on the possibility of fission of a contracting rotating fluid mass, by F. R. Moulton.
The bearing of molecular activity on spontaneous fission in gaseous spheroids, by T. C. Chamberlin.

There was also published a paper on geophysical theory under the planetesimal hypothesis, by Dr. Arthur C. Lunn; also a paper on the relations of equilibrium between the carbon dioxide of the atmosphere and the calcium

sulphate, calcium carbonate, and calcium bicarbonate of water-solutions in contact with it, by Prof. Julius Stieglitz.

Dr. Chamberlin was given leave of absence from January 1 to July 1, 1909, to serve as commissioner on the oriental educational investigation of the University of Chicago. This gave incidental opportunity for diastrophic, physiographic, and other observations tributary to studies in hand on the modes of earth-deformation. While these observations were nceessarily cursory, they were not without value in giving some personal familiarity with the facies assumed by the great deformations of the Eurasian continent. Most of the work lay in the Chinese Empire, but some reconnaissances were made in Japan and Siberia, and in northern, central, and southeastern Europe.

Aside from work on the themes previously announced, the studies of Dr. Chamberlin, since his resumption of service under the Institution, have chiefly related to diastrophism.

Moulton, F. R., University of Chicago, Chicago, Illinois. Grant No. 572. *Inquiry into the fundamental problems of geology.* (For previous reports see Year Books Nos. 4 and 5.) $2,000.

The papers published during the year are listed in the Bibliography, page 52. The work not yet published and that under preparation is:

The Probability of Near Approach of Two or More Stars, and Related Questions:

This paper was started two years ago and the first draft of it is finished. Some of the results of interest are that the probability of actual collision of suns is so small that this possibility may be neglected in questions of cosmogony, but that suns may pass relatively near one another frequently enough to make this factor an important one in celestial evolution.

Some Dynamical Considerations on Globular Star Clusters:

Read before the Astronomical and Astrophysical Society of America, August 19, 1909. In this paper it was shown that taking reasonable assumptions as to the dimensions and masses of the globular clusters, relative motions of their members will not be observable unless the measurements cover several decades.

On the Orbits of Particles Ejected from One Sun and Moving Subject to the Disturbing Influence of a Visiting Sun:

For an earlier report on this subject see Year Book No. 4 (1905), pp. 186–190. The computations described there have been extended, but the discussion of the results is not yet finished.

Periodic Orbits:

This is a book on periodic orbits being prepared in collaboration with my former students, Dr. Herbert Earle Buchanan, of the University of Wis-

consin, Dr. Thomas Buck, of the University of Illinois, Prof. Frank Loxley Griffin, of Williams College, Prof. William Raymond Longley, of Yale University, and Dr. William Duncan MacMillan, of the University of Chicago. The work is rapidly nearing completion, there being at present 600 type-written pages ready for the printer. The ultimate aim of this line of work is the treatment of the problems actually presented in the solar system by the rigorous methods of periodic orbits. In the present volume the existence and construction of a great variety of periodic orbits are given, and a number of practical problems are treated.

GEOPHYSICAL RESEARCH.

Becker, George F., U. S. Geological Survey, District of Columbia. Grant No. 226. *Variation of the moduluses of elasticity and plasticity with temperature.* (For previous reports see Year Books Nos. 3, 4, 5, 6, and 7.) $7,500.

It is expected that the experimental investigations will be completed at the end of the present fiscal year and a complete report of the entire investigation will be issued as soon thereafter as practicable.

LITERATURE.

Sommer, H. Oskar, Camberley, Surrey, England. Grant No. 489. *Preparation for publication of results of researches on Arthurian Romances.* (For previous reports see Year Books Nos. 5, 6, and 7.) $2,000.

In accordance with your instructions and the rules of the Institution, I have the honor to submit to you the following account of the work I have done since the date of my last report:

1. I revised 186 pages of volume I for the second time, and supplied side-notes and head lines to these pages.

2. I revised the whole of volume III, or 195 galleys, for the first time, 53 pages for the second time, and supplied these pages with side notes and head lines.

3. I revised 61 galleys of volume IV for the first time.

4. I transcribed the whole of volume V from the manuscript Add. 10293 at the British Museum, supplied deficiencies, collated the text with six other manuscripts, and prepared the whole for the press.

5. I supplied the preliminary matter to volume I, preface, and introduction. The latter gives but very briefly the result of my studies. The pamphlets submitted to the members of the Executive Committee all represent work connected with these studies on the origin and development of the Vulgate Version.

6. In the course of the last 19 months, more particularly since May 1 last, I have been engaged at the British Museum or at home on the Vulgate Version in transcribing the unique second part of the manuscript No. 337 of the Bibliotheque Nationale. Having recognized the importance of this manuscript in regard to the genesis of the Vulgate Version, I had its unique portion photographed in December, 1907, on a considerably reduced scale, because it is still only accessible at the Bibliotheque Nationale. Of these photographs (to the number of 180, each representing 4 closely written columns of 45 lines each, *i. e.*, 720 columns) I have so far completed 600.

In order to enable you to form a clear estimate of the present state of my work, I beg to add an account of what I have still to do to complete it:

1. Revise preliminary matter to volume I.
2. Revise about 380 pages of volume III for the second time, add side notes and head lines.
3. Revise about 139 galleys of volume IV for the first time, for the second time, and add side notes and head lines.
4. Revise first and second times the whole of volume V and add side notes and head lines.
5. Transcribe, collate with four manuscripts, prepare for press, revise first and second times, provide side notes and head lines to all of volume VI.
6. Compile general index raisonné of names and places to the 6 volumes.

METEOROLOGY.

Bjerknes, V., Christiania, Norway. Grant No. 551. *Preparation of a work on the application of the methods of hydrodynamics and thermodynamics to practical meteorology and hydrography.* (For previous reports see Year Books Nos. 5, 6, and 7.) $1,200.

Mr. J. W. Sandström left his position as a grantee of the Carnegie Institution in June, 1908, and Messrs. Th. Hesselberg and O. Devik have been chosen to assist in the work.

The systematic working out of the purely kinematic methods of investigating air or sea motions have been continued and will soon be finished. These being motions in space, special methods had first to be introduced for representing them by diagrams on plane charts. Two essentially different methods of doing this have been given and tried practically.

The problem of developing methods for passing from the scattered observations giving the velocity in different points in the atmosphere or the sea to these continuous representations of the motions has been completely worked out and the methods have been tried practically for the case of air motions, the most important observations used being those organized by the Inter-

national Committee for Aeronautic Meteorology. Sufficient observations for working out examples of the practical use of these methods in case of the sea are not at hand. The main difficulty to overcome has been that the observations give only the horizontal components of the motion, while methods for directly observing the vertical motions have not yet been found, either for the case of air or sea motions. In spite of their smallness, these motions are, however, of extreme importance meteorologically, as governing mainly the distribution of precipitation and of clear sky. Fortunately they can be derived indirectly if the horizontal motions are sufficiently well known. This derivation depends upon a proper use of the surface condition and on the equation of continuity. For the use of the surface condition proper topographic charts must be at hand. The world's map drawn for this purpose (see previous reports), and the special charts required for the working out of special examples are now nearly ready. The constructions based upon the use of the equation of continuity, referred to in the previous reports, have been still further developed and tried practically upon material of observations, both from the ground and from higher levels in the atmosphere.

Complete charts of the velocity of the medium being produced, the next kinematic problem is that of producing corresponding charts of the accelerations. These will form the basis of the later dynamic investigations. The methods of constructing these charts have been developed and tried practically in the extent in which proper material of observations has been available for us. The acceleration on the motion relatively to the earth and the acceleration due to the coexistence of this relative motion and the motion of rotation of the earth must be derived separately. The latter partial acceleration can be found at once, as soon as the charts representing the velocities have been produced.

The method of constructing charts of the horizontal and vertical components of this acceleration have been worked out and tried practically for the case of motions near the earth's surface. The application of the construction and the representation of the vector for higher levels has not yet been tried practically, but is expected to contain no special difficulty.

Satisfactory material of observation for trying practically the methods of drawing charts of the acceleration relatively to the earth has not yet been available for us. As the knowledge of these accelerations will be of fundamental nature for the further dynamic investigations, Professor Bjerknes brought before the International Committee for Aeronautic Meteorology, at its meeting at Monaco this year, a series of proposals regarding the organization of aerologic observations. As a resolution in favor of these proposals was voted, it is to be hoped that observations making possible a more thorough discussion of the aerial dynamics will be produced in the coming years. Meanwhile it will probably be possible to get unpublished material of obser-

vations from common meteorological stations, enabling us to construct these accelerations at least for the lowest strata.

The revision of the text has proceeded simultaneously with the working out of the practical examples, and the manuscript of the part "kinematics" of our work will be given off as soon as the final examples have been worked out.

NUTRITION.

Osborne, Thomas B., Connecticut Agricultural Experiment Station, New Haven, Connecticut. Grants Nos. 497 and 573. *A comparative study of the more important vegetable proteins.* (For previous reports see Year Books Nos. 3, 4, 5, 6, and 7.) $9,000.

Grant 497 ($4,000).—The lines of work followed under previous grants have been continued under this grant.

In order to obtain information respecting the relative food value of the different vegetable proteins which have been so extensively studied under previous grants, a number of food proteins of animal origin have been hydrolyzed and the proportion of their decomposition products determined according to the same methods previously applied to the vegetable proteins.

The chief proteins of hen's eggs have been prepared with especial care as to their separation from other proteins as well as from non-protein substances and the large quantities obtained have been used for the hydrolyses.

Hydrolyses have also been made of the edible muscle tissues of different types of animals—mollusk, fish, bird, mammal—with a view not only to obtain information respecting them as foods, but also to determine their biological relations from a chemical standpoint. Although distinct differences were detected between these several types of muscle, no such wide differences were found as those previously shown to exist between the reserve protein of different families of seeds.

A very extensive study was also made of the behavior of protein nitrogen under different conditions and the proportion of nitrogen in different forms of binding in a large number of different vegetable proteins. This work involved the expenditure of a great deal of labor which it is believed was justified by the results obtained.

All the results of the work thus far described have been published in papers given in the Bibliography, page 42.

An exhaustive study of the proteins of the hemp seed has been in progress for some time, the purpose of which is to obtain a better knowledge of the properties of the globulin edestin, to establish as far as possible its chemical individuality by subjecting it to all possible means for detecting the presence of two or more substances in preparations made by methods now in use and also to determine the nature and proportion of all other associated

proteins which are present in the seed. The extensive use that has been made of the globulin edestin for establishing many points of protein chemistry makes it important to know all that can be learned of the proteins of this seed. It has become evident that edestin is one of the most available proteins for such studies and the need of the information which is sought in the present investigation is evident from questions that have arisen in connection with the work previously done and now in progress in this laboratory. Much of importance has been established by the work already done, but the results are not yet ready for publication.

A detailed investigation of the methods at present available for determining the quantity of the several mono-amino-acids which proteins yield on hydrolysis has been undertaken and is nearly completed. The main purpose of this work is to obtain more definite information respecting the large deficit which even the most successfully conducted analyses always show. It was thought, by gaining more definite information as to the losses incident to the determinations of the products of hydrolysis already known, that the amount of substances of still unknown nature could be brought within narrower limits than is now possible. It was also thought that information could be obtained which would permit of a better judgment than has heretofore been possible of the real value of the analyses from a quantitative standpoint.

Like all other analytical processes, those now in use can only be perfected by long experience and careful study and the results of the work already done along these lines have shown that many minor improvements are possible. By the use of a new method of esterifying, the completeness of this process has been improved and the labor greatly diminished. The separation of leucine and valine has been greatly simplified by the application of the method of Levene and Van Slyke. Much has been learned concerning the isolation of glutaminic acid and important data obtained respecting the behavior of proline ester on distillation. Although much time has been spent on this work the results obtained have evidently justified the undertaking.

Much time has also been devoted by the writer to making the results of his past work more available for others. During the past year he has prepared a detailed account of the methods employed in making preparations of the different vegetable proteins. This account is to form a chapter in Biochemische Arbeitsmethoden, edited by E. Abderhalden. He has also just completed a monograph on the vegetable proteins which forms one of the series of monographs on biochemistry edited by Hopkins and Plimmer in England. This work includes a practically complete bibliography of all the papers relating to vegetable proteins. A detailed account of what is at present known of the different vegetable proteins has also been prepared for publication in the Ergebnisse der Physiologie. A chapter has also been contributed to the

Biochemisches Handlexicon, edited by E. Abderhalden, in which the important characters of the different vegetable proteins is given in a concise form.

Grant 573 ($5,000).—Work under this grant was begun on April 1, 1909, and thus far has involved a continuation of the uncompleted investigations begun under grant 497, which have been described in the account of the work done under that grant.

PALEONTOLOGY.

Case, E. C., University of Michigan, Ann Arbor, Michigan. Grant No. 559. *Completion of work on the Permian reptiles of North America.* (For previous reports see Year Books Nos. 2 and 4.) $1,600.

Since June 28 I have been in the American Museum of Natural History in New York and will continue there until some time in September. Over 200 pages of manuscript notes have been prepared, and 109 pen drawings, which will be increased to 130 or 140; also 35 photographs. The summer's work will complete the review of the material in the American Museum. Succeeding work will be upon the material in Chicago University, in foreign museums, and upon newly acquired material.

I have had the advantage of over a week's conference with Dr. Robert Brown, of Victoria College, Stellenbosch, South Africa, the admitted authority on the Permian reptiles of South Africa, and this has led to interesting conclusions regarding the interrelations of the groups.

There have been no preliminary publications as yet, but several will be prepared during the coming winter.

Wieland, George R., Yale University, New Haven, Connecticut. Grant No. 552. *Continuation of investigations on American fossil cycads, and particularly for the preparation of a volume on "The Taxonomy of American Fossil Cycads."* (For previous reports see Year Books Nos. 2, 3, 4, 6, and 7.) $2,000.

Early in last year it was decided to extend the investigation of the fossil cycads by engaging in the study of the plant-bearing horizons of the southern portions of the continent. As nothing was known of the extent to which the cycadeoidean floræ might be represented in Central America and Mexico, it was considered most opportune that the Geological Survey of the latter country had offered to share in these researches. Accordingly, field-work was begun in western and southern Oaxaca March 3, and continued until July 20. The results of exploration in this little-studied region have fully realized all earlier anticipations. An accurate section has been made through a great series of plant beds over 600 meters in thickness, and their Rhætic-Liassic age determined from the most extensive cycadophytean flora thus far found in America. These horizons are not only of wide extent in Oaxaca, but are

known to continue westerly into Guerrero. They are exceedingly prolific in fossil plants, preserved as imprints, casts, molds, and occasionally silicified; and because of this fact, taken together with the important period of origins represented, the possibilities opened up for future work of prime interest and importance are indeed great. Obviously, too, because of the far southerly position, virtually between the western continents, these new floræ have especial value with reference to all problems of former plant distribution.

The extensive collections had to be transported on the backs of burros over the mountains to the nearest railway station, a distance of 120 miles. They include in particular the most recent lepidodendrids yet found, and a fine display of *Williamsonia* fruits. Hitherto such have only been obtained in any sufficient number and preservation to afford opportunity for comparative study on the Yorkshire coast and the Gondwanas of India. The laboratory preparation of these unique fossil plants has been completed, and their illustration and description in the form of a memoir on the Williamsonia Flora of the Mixteca Alta is nearly complete.

The successful prosecution of the Mexican work thus briefly outlined has taken up time to such an extent that the immediate preparation of the manuscript of the volume on the Taxonomy of the American Fossil Cycads has not been carried much beyond the stage announced last year. But it is intended to resume the work of preparation of this volume as early as possible.

PHYSICS.

Barus, Carl, Brown University, Providence, Rhode Island. Grant No. 574. *Continuation of study of the properties of condensation nuclei, including ions.* (For previous reports see Year Books Nos. 4, 5, and 7.) $500.

Professor Barus makes use of Thomson's method of measuring the charge of an electron in terms of the velocities of ions and their number. The latter datum, however, is determined from the angular diameter of the coronas of cloudy condensation, produced in a cylindrical fog chamber under given conditions of rapid partial exhaustion. By providing the chamber with an electrically charged axial aluminum tube within which are sealed tubelets of radium acting through the aluminum walls in virtue of the gamma rays, the fog chamber becomes an electrical condenser whose ionization may be varied. The electric current passing from core to the shell of the cylindrical condenser may therefore be measured by a sensitive electrometer. If it be assumed that negative ions only are caught in the fog chamber used, and if the author's earlier and independent results are employed for stating the nucleation values of the coronas, the following data are typical for the enormous ionizations used: Total number of ions per cubic centimeter, 1,700,000, 385,000, 135,000; corresponding value of 10,000 million times the electrical charge, 4.4, 3.6, 3.9 electrostatic units, respectively.

The results show that the displacement of ions during exhaustion is the most serious source of discrepancy. On the other hand, the effect of gamma rays on the outside of the fog chamber and of conduction currents is almost negligible for a well-installed apparatus. In connection with this discussion Dr. Barus undertakes the electrometric measurement of the voltaic potential differences between the two conductors of a condenser separated by an ionized medium.

A summary of the work during the last two years has been completed and will appear as part 2 of Publication 96 of the Carnegie Institution of Washington.

Burgess, Charles F., University of Wisconsin, Madison, Wisconsin. Grant No. 560. *Investigation upon properties of iron and its alloys, based upon the use of electrolytic iron.* (For previous reports see Year Books Nos. 4, 5, 6, and 7.) $2,500.

Mr. James Aston has devoted his entire time to the investigation during the past year and has been assisted by Messrs. G. A. Roush and J. M. Breckenridge. 523 pounds of single-refined and 300 pounds of double-refined electrolytic iron have been produced. This has been used in the production of test samples and in supplying material to other investigators. Besides a large number of alloys prepared previously, 87 new alloys have been added to the collection, including practically carbon-free alloys of iron with manganese, arsenic, bismuth, antimony, nickel, silicon, aluminum, and zinc.

The greatest amount of attention has been given to the testing of the magnetic properties of alloys, and nearly 1,000 magnetic records have been obtained. The electrical resistance and other physical properties have also been investigated. Methods of magnetic measurements have been studied and comparisons are being made with results obtained in industrial laboratories.

A study of the corrodibility of about 100 alloys is still under way, with a view to determining the influence of the metallographic structure of alloys on the corrodibility and the comparative value of rapid methods of testing corrosion with corrosion produced by atmospheric conditions.

The publications of results which have been made during the past year include the following:

Observations of alloys of electrolytic iron with arsenic and bismuth, by C. F. Burgess and James Aston.

Influence of arsenic and of tin upon the magnetic properties of iron, by C. F. Burgess and James Aston.

The absorption by iron of carbon from carbon monoxide, by Charles F. Burgess and James Aston. A paper for the International Congress of Applied Chemistry.

Effect of temperature on the magnetic properties of electrolytic iron, by E. M. Terry. Preliminary report to American Physical Society, November, 1908; publication in full in Physical Review in near future.

Other papers which are in the printer's hands or ready for publication include the following:

Physical properties of iron-copper alloys.
Observations on the alloys of iron and manganese.
The physical characteristics of alloys of iron free from carbon.
Tests on alloys of iron for permanent magnets.
The electrical resistance of iron alloys.
Magnetic and electrical tests on iron-copper alloys.
Physical properties of iron and nickel alloys.
Magnetic and conductivity tests on iron-nickel alloys.

Howe, Henry M., Columbia University, New York, New York. Grant No. 561. *Completion of work of determination of the influence of ingot size on the degree of enrichment of the segregate in steel ingots, and the homogeneousness of the ingots outside the region of maximum enrichment.* (For previous reports see Year Books Nos. 6 and 7.) $500.

The last two grants (December 8, 1908, $200, and March 17, 1909, $300) were for completing the investigation and in particular applying the Baumann method of silver-printing to the ingots already examined and others. Both these things have been done. A comparison of the results obtained by a large number of observers, myself included, of ingots of various sizes shows clearly that the degree of enrichment increases with the size of the ingot, especially when this exceeds a moderate size, say about 20 inches square. The influence of other variables is so great that it was necessary to eliminate them by taking the average of a very large number of cases before it became possible to prove clearly the positive effect of ingot size. What is even more valuable than this is the fact, brought out incidentally by the investigation, that with skill and care segregation can be restrained within limits which are negligible for most purposes, even in ingots as much as 20 inches square, so that there is no real need of greatly restricting ingot-size in order to prevent segregation.

Eleven ingots have been examined by the Baumann silver-printing method. The results indicated that, though the method is valuable for a preliminary reconnaissance, to indicate approximately the position of the richest spots, so that if it had been invented at the time I began this investigation it might have saved much time and money, yet its indications are not so precise as to make it applicable to a series of ingots which has already been investigated so thoroughly as those have which I have been studying.

Besides the publications already reported, a paper giving some of the results of this investigation has appeared in Bulletin 34 of the American Institute of Mining Engineers, p. 909, Oct., 1900.

Nichols, Edward L., Cornell University, Ithaca, New York. Grant No. 575. *Continuation of researches on fluorescence and phosphorescence.* (For previous reports see Year Books Nos. 4, 5, 6, and 7.) $3,000.

During the past twelve months the work on fluorescence and phosphorescence carried on by or under the direction of Prof. Ernest Merritt and myself in the Physics Laboratory of Cornell University has consisted of the following researches.

The Experimental Determination of the Actual Distribution of Energy in Various Fluorescence Spectra:

In this investigation the visible spectrum of our acetylene standard flame was compared with spectrum of an ideal black body of known temperature, and from these measurements the distribution of energy in the spectrum of the standard flame was computed by the application of Wien's law. From these data the distribution of energy of any source of light that has been properly compared with the standard can be computed. Careful spectrophotometric studies of the fluorescence spectra of solutions of fluorescein, eosin, and resorufin have been made; corrections for absorption and slit-width have been applied and the energy curves for these fluorescent substances determined. The relation of these curves to the energy curves of the spectra of incandescent black bodies is of great interest and the development from entirely independent considerations of equations describing this important type of luminous emission is in progress.

The Determination of the Influence of Wave-length upon the Effectiveness of Monochromatic Radiation in Exciting Fluorescence:

In these experiments we dispersed the light from a Nernst filament by means of a large spectrometer and used successively various wave-lengths of the continuous spectrum of this source in the excitation of the fluorescence of a number of liquids. The brightness of the exciting light was measured and the brightness of the fluorescence produced was determined. The absorption coefficient of the fluorescent liquid for each wave-length was likewise determined. We were thus enabled, by means of the data established in the course of the work already described, to compute the relative effects of equal amounts of energy of absorbed light of the various wave-lengths in producing fluorescence. The experimental data of this research are complete and the results are now being prepared for publication.

The Quantitative Study of the Effects of Low Temperature upon Fluorescence Spectra:

Some years ago Dewar and other writers published observations upon the effect of low temperatures on the brightness and color of phosphorescent substances, and the first of our present series of papers (Physical Review, vol.

XVIII, p. 355, 1904) dealt with those changes in the fluorescence and phosphorescence of nearly 200 substances under the action of ultraviolet light and the X-rays, which could be directly noted by inspection when the substances were cooled to the temperature of liquid air. Up to the present time, with the exception of an important photographic investigation by Becquerel, nothing further has appeared.

Our present work consists in measurements with the spectro-photometer of the fluorescence bands of several typical substances (willemite, anthracene, resorufin, and fluorescein) at temperatures ranging from +20° C. to —185° C.

The data obtained make it possible to plot the energy curves of the fluorescence spectra of these substances for any temperature within these limits, to indicate the effect of temperature upon the intensity of any wave-length of the spectrum, and to describe the progressive changes as regards intensity, width, and location of the various bands.

The remarkable shifting and narrowing of the fluorescence bands, together with successive increases and diminutions of intensity with lowering temperature, indicate a complexity of phenomena that can be elucidated only by further study, and measurements are now in progress upon the corresponding variations in the absorption spectra of these substances when cooled to the temperature of liquid air.

Mr. R. C. Gibbs, under our direction, has made a very complete spectrophotometric study of the effect of temperature upon the absorption and fluorescence of uranium glass. The range of temperature in his experiments is from 300° C. to —185° C.

The experiments on short-time phosphorescence, the beginnings of which were described in the Physical Review, vol. XXVII, page 209, have been continued throughout the year by Dr. C. W. Waggoner, who made use of the new "wheel" phosphoroscope; a form of instrument especially devised for this investigation. He has also been engaged in the development of methods of preparing phosphorescent compounds of known composition and definite heat treatment in the electric furnace and has produced several series of such compounds in which manganese, cadmium, etc., are the active components. In this work he was assisted by Mr. B. H. De Long, a chemist paid from the funds placed at our disposal by means of the grant from the Carnegie Institution of Washington.

Mr. H. E. Howe has completed an experimental investigation, highly instructive although negative in result, concerning the electrical conductivity of fluorescent vapor of anthracene.

Dr. C. A. Pierce has continued his extended photographic studies of thermo-luminescence, the earlier results of which were published in two papers in the Physical Review (vol. XXVI, pp. 312 and 454).

Mr. F. K. Richtmyer has greatly extended his study of photo-electric cells (Physical Review, XXIX, p. 71), particularly with reference to their selectivity, and has developed a method, by means of such cells, for following the decay of phosphorescence long after it becomes too feeble to permit of visual measurement.

Miss Louise McDowell has completed her extended observation of selenium films and finds the analogy between the change of conductivity of this substance and the decay of phosphorescence such as to suggest a similar origin of the two phenomena.

PHYSIOLOGY.

Loeb, Leo, University of Pennsylvania, Philadelphia, Pennsylvania. Grant No. 582. *Study of the toxic action of the poison of Heloderma suspectum.* (For previous reports see Year Books Nos. 6 and 7.) $500.

I herewith submit the following report of work done during the past year under the grant for the study of the toxic action of the venom of *Heloderma suspectum.* The following problems were investigated:

(1) The conditions upon which depends the absorption of venom.
(2) Structural changes produced in the body under the influence of acute and of chronic intoxication.
(3) The conditions upon which the production of hemorrhagic erosions and ulcers of the stomach depend under the influence of the venom.
(4) The influence of venom upon the circulation and respiration.
(5) The effect of pilocarpine on the structure of the venom-gland.
(6) The transplantation and regeneration of the venom-gland.

Researches into the chemical character of the venom are still proceeding. The work will probably be concluded in the course of next winter.

POLITICAL SCIENCE.

Rowe, Leo S., University of Pennsylvania, Philadelphia, Pennsylvania. Grant No. 577. *Study of the federal system of Mexico.* $1,500.

The first few weeks of my stay in Mexico were devoted exclusively to the preparation of a calendar of the available constitutional documents. Fortunately this material is fairly complete and makes possible the study, through original sources, of Mexico's constitutional development. At present the following chapters of the monograph are in final form:

CHAPTER I.—*The Bases of the Mexican Federal System and the Antecedents of the Constitution of 1857:*

Political conditions prevailing prior to 1857. Attempts at constitutional organization, with special reference to the "Iguala Plan" of February 24, 1821, the Constitution of October 4, 1824, the "Seven Constitutional Laws" of December 29, 1836, the "Organic Bases" of June 12, 1843, the "Plan of Ayutla" of March 1, 1854, and the "Plan of Acapulco" of March 11, 1854.

CHAPTER II.—*The Provisional Organic Act of May 15, 1856, and the Constitution of February 5, 1857:*

Analysis of the work of the Constitutional Convention of 1856–57. Report of the Committee on Draft. Reception given the report by the Convention. Irreconcilable differences of opinion. Adoption and promulgation of the constitution.

CHAPTER III.—*Amendments to the Constitution of 1857:*

In this chapter the numerous amendments to the Mexican Constitution are studied and the conditions which necessitated them are analyzed.

The following chapters are required to complete the monograph:

Chapter IV. The reform laws.
Chapter V. The organization of the Federal Government.
Chapter VI. The division of functions between Federal and State governments.
Chapter VII. The constitutional position of the States.
Chapter VIII. Constitutional guarantees under the Mexican Constitution.
Appendices:
I. Bibliography.
II. Documents illustrative of the constitutional development of Mexico.

The difficulties involved in the study of the Mexican political system are greatly increased by reason of the fact that the existing histories of Mexico, especially those that deal with the critical periods of the country's constitutional development, are untrustworthy, owing to the pronounced partisan standpoint from which they are written.

The same is true, although for reasons of a different nature, of the numerous commentaries on the Constitution. Without a single exception, Mexican constitutional writers have dealt with the "paper constitution" rather than with the actual political system of the country. Instead of analyzing the institutional life of the country, the purpose of the commentators seems to be to create the impression that Mexico has reached the highest stage of democratic development and that the study of the written constitution is sufficient to obtain an accurate acquaintance with the political institutions of the country. Fortunately, the documentary material for the study of the constitutional development of the country has been preserved and is readily accessible.

The first task, therefore, was to undertake a study of the bases of the Mexican Federal system and the antecedents of the Constitution of 1857. This is the ground covered in Chapter I.

SYNOPSIS OF CHAPTER I.

The Bases of the Mexican Federal System and the Antecedents of the Constitution of 1857.

(1) Analysis of contrast between the political condition of Mexico and that of the United States immediately after the declaration of independence from the respective mother countries.

(2) Persistence of the monarchical idea in Mexico and its effect on the constitutional development of the country. The constitution of Apatzingan of October 22, 1814.
(3) The "Iguala Plan" of February 24, 1821, with its provision for a constitutional monarchy and the Treaty of Cordoba of August 24, 1821.
(4) The Iturbide Empire.
(5) The Constitutional Convention of 1823 and the Constitution of 1824. Division of opinion within the Convention between Federalists and those favoring a centralized form of government. Influence of the Spanish Constitution of 1812. The struggle between Federalism and centralization in Mexico as compared with the Argentine Republic. Triumph of the Federal plan by vote of June 12, 1823.
(6) The "Acta Constitutiva" of January 31, 1824, and the Constitution of October 4, 1824.
(7) The period of anarchy (1824–1835).
(8) The ascendancy of Santa Anna and the downfall of the Federal system. The "Seven Constitutional Laws" of December 29, 1836.
(9) Reappearance of agitation and "Pronunciamientos" in favor of the Federal system.
(10) Simplification of the "Seven Constitutional Laws" in the "Organic Bases" of June 12, 1843.
(11) Decree of Jose Mariano de Salas (August 22, 1846) reestablishing the Federal system and declaring the Constitution of October 4, 1824, in full force and effect pending the convening of a Constitutional Convention.
(12) Political disintegration of the country. Renewed dictatorship of Santa Anna.
(13) The "Plan of Ayutla" of March 1, 1854, and the "Plan of Acapulco" of March 11, 1854.
(14) Provisional Presidency of Comonfort (December, 1855) and the conflict between church and state.

Synopsis of Chapter II.

The Provisional Organic Act of May 15, 1856, and the Constitution of February 5, 1857.

(1) The assembling of the Constitutional Convention, February 18, 1856. Unfortunate political conditions of the period. Bitterness of party feeling. Influence of the clergy.
(2) Appointment of the "Committee on Draft."
(3) Decree of Provisional President Comonfort (May 15, 1856) putting into operation a Provisional Organic Statute pending the adoption of the new Constitution. Memorandum of the Secretary of Government (May 20, 1856) explaining the provisions of the statute.
(4) Report of the "Committee on Draft," June 16, 1856. Analysis of the report. Differences of opinion within the Convention. The Bill of Rights. Discussion thereon. Failure of attempt to secure religious tolerance. Opposition of the committee to the bicameral system. Plan proposed for the settlement of conflicts between Federal and State authorities.
(5) Influence of the Constitution of the United States on the draft submitted by the committee.
(6) Adoption of the Constitution (February 5, 1857). "Manifesto" to the nation. Promulgation of the instrument.
(7) Critical study of the Constitution of 1857.

Synopsis of Chapter III.

The Amendments to the Constitution of 1857.

(1) Amendment providing for the separation of church and state (September 25, 1873).
(2) Amendment providing for a bicameral legislature (November 13, 1874).
(3) Amendment granting to the President of the Republic a suspensive veto (November 13, 1874).
(4) Amendment granting additional powers to the Congress (November 13, 1874).
(5) Amendment defining the powers of the Permanent Committee (Diputacion Permanente) of the Congress (November 13, 1874).
(6) Amendments of May 5, 1878:
    a. Prohibiting the election of a President for two consecutive terms.

b. Prohibiting the reelection of State governors for two consecutive terms.

(7) Amendment abolishing on December 1, 1884, the "alcabalas" and prohibiting the collection of customs dues on goods transported from one State to another (May 17, 1882).

(8) Amendments of June 2, 1882, relating to the power of the Congress to give recompense for services rendered to the country and to grant patents and copyrights.

(9) Amendment determining the incumbency of the presidency in case of death or disability of the Chief Executive (October 3, 1882).

(10) Amendment relating to the liberty of the press (May 15, 1883).

(11) Amendment granting to the federal government the power to provide commercial and mining codes (December 14, 1884).

(12) Amendment defining the jurisdiction of the federal courts (May 29, 1884).

(13) Amendment extending to December 1, 1886, the period for the abolition of "alcabalas" and customs dues between the States (November 26, 1884).

(14) Amendment providing for the formation of the Territory of Tepic through cession to the Union by the State of Jalisco (December 12, 1884).

(15) Amendment restricting the powers of the States with reference to interstate commerce (November 22, 1886).

(16) Amendment of October 21, 1887:

a. Permitting the reelection of the President for a second term, but prohibiting a third term unless a period of four years shall have intervened between such second and third term.

b. Extending similar requirements to the office of State governor.

(17) Amendment abolishing all restrictions relating to the reelection of the President (December 20, 1890).

(18) Amendment of April 24, 1896:

a. Giving to the Congress the power to elect a provisional President in case of temporary or permanent disability of the President and prescribing procedure in such cases.

b. Prescribing the procedure in granting leave of absence to the President.

(19) Amendment further limiting the powers of the States (May 1, 1896).

(20) Amendments of June 10, 1898:

a. Prohibiting the establishment of monastic orders.

b. Defining the obligations and rights of citizenship.

(21) Amendment reorganizing the Federal courts (May 22, 1900).

(22) Amendments of May 14, 1901:

a. Defining the cases in which the death penalty may be inflicted.

b. Prohibiting the acquisition by religious corporations or institutions of real estate other than that absolutely necessary for the purpose for which they were established.

(23) Amendments of October 31, 1901:

a. Abolishing the requirement that the local authorities in the Federal District and in the Territories shall be elected by popular vote.

b. Extending the powers of the Federal government over forts, barracks, and other property necessary to the performance of Federal functions.

(24) Amendments of December 18, 1901:

a. Limiting the power of the States to issue bonds.

b. Increasing the basis of representation in the Chamber of Deputies from one representative for every 40,000 inhabitants to one representative for every 60,000.

(25) Amendment providing for the formation of the Territory of Quintana Roo (November 24, 1902).

(26) Amendments of May 6, 1904:

a. Increasing the powers of the Chamber of Deputies.

b. Defining the powers of the Permanent Committee of the Congress.

c. Increasing the term of the President and Vice-President to six years.

d. Re-establishing the office of Vice-President and determining the conditions of his succession to the Presidency.

e. Prescribing the oath of office of President and Vice-President.

f. Prohibiting the President and Vice-President from leaving the territory of the Union without the consent of the Chamber of Deputies.

g. Defining the criminal liability of Federal officials.

CHAPTER IV.—*The Reform Laws:*

A brief consideration of these laws is necessary, as they constitute an integral part of the constitutional struggle between the church and the state. The material for this chapter is in hand, but has not as yet been co-ordinated for final writing.

The remaining chapters of the monograph for which material must be collected are:

Chapter V. The organization of the Federal Government.
Chapter VI. The division of functions between Federal and State governments.
Chapter VII. The constitutional position of the States.
Chapter VIII. Constitutional guarantees under the Mexican Constitution.
Appendices:
1. Bibliography.
2. Documents illustrative of Mexican constitutonal development.

PSYCHOLOGY.

Franz, Shepherd Ivory, Government Hospital for the Insane, Washington, District of Columbia. Grant No. 80. *For investigation of the functions of the cerebrum, with special reference to the functions of the association areas.* (For previous reports see Year Books Nos. 4, 5, 6, and 7.) $1,000.

During the year work on the functions of the parieto-occipito-temporal lobes has been continued with satisfactory progress. New work on the relation of the occipital lobes to visual sensations and perceptions has also been in progress and a preliminary account of the findings will be published shortly. In connection with the investigation of the functions of the cerebrum, special tests and observations on the intelligence of monkeys were made under my direction by Mr. William T. Shepherd, and the account of the results of the various experiments and observations is almost ready for the press.

No publications pertaining to the grant have been made during the year.

ZOOLOGY.

Castle, W. E., Harvard University, Cambridge, Massachusetts. Grant No. 562. *Continuation of experimental study of heredity in small mammals.* (For previous reports see Year Books Nos. 3, 4, 5, 6, and 7.) $1,000.

The increased grant for the current year has made possible the enlargement of breeding experiments with small mammals, which were already in progress, and the undertaking of desirable new lines of experimentation.

The experiments with rabbits have been directed chiefly toward a more precise determination of the laws of inheritance of size and of proportions of parts, matters which the experiments of previous years had shown to be not in conformity with Mendel's law of heredity. Some unsolved problems of color-inheritance have also been given further study.

The experiments with guinea-pigs have been concerned, in part, with the effects of selection upon variations in size occurring within a single race of guinea-pigs, that described in Publication No. 49, Carnegie Institution of Washington. This experiment has now been in progress for two years, and is in immediate charge of a research student, Mr. C. C. Little. By selecting at birth, from the same litters of young, the largest and the smallest individuals, respectively, it has been possible to establish two subraces distinctly different in average size, though still intergrading. It remains to differentiate these subraces, if possible, until they no longer intergrade, and then to test the stability of the distinction established between the two races. The polydactylous character of this family of guinea-pigs (see Publication No. 49), which was originally built up by selection, has fully maintained itself through the several generations which have intervened since selection for this character was suspended.

The hybridization experiments between the female guinea-pig and the male *Cavia aperea* have this year made good progress. In these unquestionable "true species crosses" the same laws of heredity govern as in crosses between different varieties of guinea-pig. The same sharp Mendelian dominance and segregation of color-characters occur among the hybrids as among guinea-pigs, while the polydactylous character shows the same imperfection of dominance and segregation, and skeleton dimensions and proportions are as in guinea-pigs fully blending.

The half-blood hybrids resulting from a first cross are fertile in the female sex, but without observed exception sterile in the male sex; the same is true of the quarter-blood *aperea* hybrids resulting from crosses of the female half-bloods with the male guinea-pig, so far as yet tested. One-eighth blood and one-sixteenth blood *apereas* are now being produced in considerable numbers, and it will be interesting to see whether fertile males will occur among these. With each successive cross since the first the wild disposition of the *aperea* occurs in diminished intensity, indicating that this does not have its basis in a simple Mendelian character. Selection experiments for modification of Mendelian color-characters by processes other than mutation are being continued with apparent success. Evidence for the existence of Mendelian units is not thereby weakened, but the fact is shown that these units are modifiable.

The experiments with rats have been directed chiefly toward the same theoretical question, the modifiability of Mendelian characters. It has been shown that by selection the extent of the pigmented areas on piebald rats may be gradually and permanently altered. Two races of "hooded" rats have now been established which no longer intergrade, while in one of these the extent of the pigmentation has been so increased that this series now intergrades with the "Irish," a variety originally quite distinct from the hooded, and characterized by pigmentation much more extensive. In this investigation I have been fortunate to have the assistance of Dr. John C. Phillips, research

fellow in biology in Harvard University, who has both provided means for greatly increasing the number of animals under observation and has kept the records of the experiments with great care.

The valuable material and surgical assistance of Dr. Phillips has also made possible a new line of experiments of much theoretical interest, in the transplantation of germ-cells from one mammal to another. Contrary to some earlier but in our view uncritical experiments with birds and mammals, we have been able to show that the ovary transplanted from one animal to another probably retains its original character without modification by the changed environment of the body into which it was introduced. Out of many experiments we have as yet obtained one positive result. An albino female guinea-pig into which were transplanted the ovaries of a black guinea-pig bore a litter of two black-pigmented young sired by an albino male guinea-pig. Since normal albinos produce only albino young, it is evident that these young developed from ova liberated by the introduced ovaries. Further, their character was such as might have been that of young borne by the black guinea-pig herself had she been mated with the albino male in question, instead of merely furnishing ovarian tissue to the albino female. Sweeping generalizations must, of course, not be drawn from this single case, but it certainly does not favor the view that environmental influences can directly induce germinal ones.

The experiments with mice, in charge of Mr. C. C. Little, have shown the existence of two different modifications or "dilutions" of the pigmentation, which behave as independent Mendelian characters in heredity. In one the coat is pale, but the eye pigmented; in the other the pigmentation of both coat and eye is affected. The case, however, can not be explained by the assumption of an independent factor for eye-pigmentation different from that of the coat, as Cuénot has suggested, for each modification actually affects the coat pigmentation, but in a different way. Three papers have been published this year (see Bibliography, page 49) and two are now in press.

Castle, W. E., and **Mark, E. L.**, Harvard University, Cambridge, Mass. Grant No. 492. *Continuation of experimental studies in heredity.* (For previous reports see Year Books Nos. 3, 4, 5, 6, and 7.) $500.

A separate grant has been made to Dr. Castle for the continuation of his work in this field.

Dr. Mark reports that, owing to the heavy duties of instruction assumed by Dr. Copeland at the beginning of last year, it was impossible for him to revise for publication the paper on the "Spermatogenesis of the Honey Bee and the Wasp," which was nearly ready for the printer a year ago. In its revised form this paper will, however, be soon submitted for publication.

In accordance with the plans stated in his report for 1907–08, Dr. Mark has given time chiefly to the study of the hymenopterous parasites of the

eggs of certain insects. Although not securing the student assistance anticipated, he was able to make considerable progress with the work, and has, with the aid of a technician to make preparations, secured much valuable material covering early stages of development. A part of this material has been sectioned and mounted—several thousand sections in all. A preliminary study of the sections has been made, and sketches of several stages have been drawn.

Unfortunately, in the early winter the insect eggs, which were being kept in cold storage and brought forward as occasion required, all died, so that it was impossible to keep up the parasitism during the year, as had been expected. This is the first time that such a catastrophe has overtaken the eggs kept in cold storage, and it is hoped that it can be prevented in future.

The work will be continued during the coming winter, and it is hoped that a paper on the results may be submitted during the current year.

As the balance of the aid still unexpended is larger than anticipated, no additional grant will be asked for the coming year.

Crampton, Henry E., Columbia University, New York, New York. Grant No. 563. *Study of variation, mutation, heredity, and geographical distribution of Polynesian species of Partula.* (For previous reports see Year Books Nos. 6 and 7.) $2,500.

Although my work is scarcely half over, it is progressing satisfactorily and conditions seem to be favorable for the investigations in the Tonga and Samoa groups, even at this time of the year. The survey of certain portions of the Society group has given some unexpected and extremely gratifying results. The same is true of the short but adequate study of the Cook Islands. If the studies at Samoa give definite results at once, I will immediately prepare and forward a statement at the earliest possible moment.

Howard, L. O., U. S. Department of Agriculture, Washington, District of Columbia. Grant No. 250. *Preparation of a monograph on American mosquitoes.* (For previous reports see Year Books Nos. 2, 3, 4, 5, 6, and 7.) $3,000.

Although no grant was made to the mosquito monograph during the last year, it may be well to make a brief statement to the following effect:

The past year has been devoted to a completion of the manuscript and to the preparation of illustrations. Some additional material has been received.

The manuscript for the systematic portion of the monograph is now completed. It covers 2,700 typewritten pages and will occupy three volumes. A fourth volume, considering the subject of remedies, carriage of disease, and a general consideration of all matters relating to mosquitoes, is practically completed and the finishing touches are now being given to it. A very large series of illustrations is ready, but there are still a number to be made. These,

however, are to be drawn as rapidly as is consistent with the extreme care required.

It is hoped to submit the whole work for publication by January 1, 1910, but of course it is possible, through delays at present unforeseen, that the time may be extended.

Mark, E. L., Harvard University, Cambridge, Massachusetts. Grant No. 564. *Study of maturation and early stages in the development of the ova of mice and rats.* (For previous reports see Year Books Nos. 5, 6, and 7.) $100.

The paper prepared in conjunction with Dr. Long has not yet received its final revision; but this is not owing to any deficiency on the part of Dr. Long; it is due solely to my inability to find time during the college year to do more than carry on the work on parasitism in insects. The revised paper will, however, be submitted for publication in the course of a few weeks.

The attempt to produce hybrids between rats and mice by means of artificial insemination, to which I referred in my last report, has not proved successful. The work was undertaken by Mr. S. Morgulis. After some preliminary trials with artificial insemination of mice with the seminal fluid of mice, attempts were made to fertilize the ova of white mice with the spermatic fluid of white rats. About twenty-five such experiments were made with suitable precautions to exclude the possibility of previous or subsequent fertilization in the normal way. In no one of these experiments were there any signs of fertilized ova. From the constantly negative results obtained it seemed undesirable to continue the experiments further. The surviving animals of the stock have, however, been kept for the purpose of carrying on other studies connected with problems contemplated in the original grant.

Naples Zoological Station, Naples, Italy. Grant No. 553. *Maintenance of two tables for American biologists.* (For previous reports see Year Books Nos. 2, 3, 4, 5, 6, and 7.) $1,000.

The privilege to make use of the facilities offered by the Zoological Station have been duly granted to Dr. Harold S. Colton, of Philadelphia, who worked from October 26, 1908, to April 1, 1909; Dr. S. Paton, from October 31, 1908, to April 29, 1909; Dr. Shigio Yamanouchi, of the University of Chicago, from December 25, 1908, to February 27, 1909.

Dr. Stewart Paton has now, after a sojourn of several years at the Naples Zoological Station, returned to the United States.

As already reported on a former occasion, I am not able to summarize the aforesaid scientists' investigations after their recent sojourn at the Zoological Station and repeat that an abstract of their work would best be given by themselves.

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